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THE STATE AGRICULTURAL COLLEGE

Fort Collins, Colorado

COLORADO AGRICULTURAL EXPERIMENT STATION

PUBLICATIONS OF 1923 AND 1924

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SODIUM ARSENITE AS A KILLING AGENT IN GRASSHOPPER BAITS

C. L. CORKINS

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SODIUM ARSENITE AS A KILLING AGENT IN GRASSHOPPER BAITS

By C. L. Corkins

Deputy State Entomologist

Commercial crude white arsenic, containing from 90 to 98 percent As_2O_3, has become the standard killing agent in poison bran-mash baits in the United States and Canada, not so much because it gives general satisfaction, but because it is cheap and available in unlimited quantities.

The field worker in grasshopper control finds that one of the greatest problems he must face is that of getting the farmer to properly mix the poison mash. This difficulty is due largely to the fact that the white arsenic is extremely heavy, making the dry mix with bran difficult and in the second place, it is only slightly soluble in cold water, making the wet mix faulty unless constant and vigorous agitation is kept up. These factors during the mixing process account for much of the erratic results often reported from the use of this insecticide.

Becoming dissatisfied with the white arsenic for the reasons stated, the writer began to examine into the possibilities of some other poisoning agent for the bran-mash. Since burning of foliage is not a factor to be taken into consideration in this case, soluble compounds were resorted to. Of these, sodium arsenite seemed the most promising. The findings here recorded may not justify the immediate replacement of the use of white arsenic by sodium arsenite, but are given to indicate the possibilities of this soluble arsenical and induce further investigation at other institutions.

HISTORY OF ITS USE

Sodium arsenite was probably first used as a killing agent in grasshopper baits in South Africa.

"It is said to have been first tried out by a Natal sugar planter, Mr. Gilbert Wilkinson, who, about the year 1894, employed it to destroy the swarms of locusts which visited his plantation. He noticed that the insects were attracted by the waste molasses of the sugar mill and consequently used it as a bait, mixing it with different poisons. Preliminary trials showed that arsenic trioxide dissolved in water by the aid of sodium hydroxide was the most efficient and economical poison to mix with the molasses. The use of this arsenical mixture was subsequently adopted and developed by the Natal government and its superiority over all other chemical and mechanical devices was clearly recognized. Later, at the suggestion of Mr. C. P. Lounsbury, the solution made by heating arsenic trioxide with a solution of sodium hydroxide or sodium carbonate was replaced by a solution of sodium arsenite."[1]

At the present time, South Africa is using commercial sodium arsenite in the powdered form, the analyses of which vary from 75 to 84 percent in white arsenic (As_2O_3) equivalent and from 10 to 20 percent sodium oxide (Na_2O). To prepare the poison, 112 pounds of sodium arsenite ($Na(AsO_2)_2$) is dissolved in eight gallons of hot water, the solution made up to ten gallons, allowed to cool and then put in a metal drum. To this, 24 gallons of mill treacle, molasses or a sugar solution is added, and the drum sealed. For use this concentrated poison is diluted, one to fifty with water, and sprayed on the swarms of 'hoppers in the early nymph stages and upon the surrounding grass. The killed vegetation is later burned.

In some few instances, they use a bait of bran or green foliage. One pound of sodium arsenite is dissolved in fifteen Imperial gallons of water, and applied to 150 to 200 pounds of green stuff or bran. For adult locusts it is used a trifle stronger.

In the United States, sodium arsenite seems to have been first experimented with extensively by F. L. Washburn, State Entomologist of Minnesota, (2). He reports the development of a spray formula, containing sodium arsenite and molasses of such a dilution that it will not kill vegetation, yet is efficient in the destruction of the grasshoppers. In addition to this, the following extract from Professor Washburn's report is of interest.

"Our field workers reported only partial success with poison baits, represented by poison bran mash and Criddle Mixture, but have, in the course of their work, hit upon a rather unique poison which they have courteously called the Minnesota Mixture. Finding that arsenite of soda used as a spray and combined with molasses was very effective against grasshoppers, they substituted this for Paris green used in making the Criddle Mixture. They used the following formula: Sodium arsenite, one pound; horse manure, 120 to 150 pounds; cheap molasses, one pint. The arsenite of soda was dissolved in the water, then added to the manure, stirring it well."

That sodium arsenite as a killing agent in grasshopper baits has not been developed further from this point can perhaps be explained mainly by the fact that it has not been, until recently, commercialized to any extent in this country. Since it is now a common product upon the market in the form of weed killers, experimentation in its uses in poison bran-mash will undoubtedly receive considerable impetus.

EXPERIMENTS WITH SODIUM ARSENITE

THE SODIUM ARSENITE USED

The sodium arsenite used in the experiments was that known as "Ussco Weed Killer." The manufacturers have kindly furn-

ished us with the following analysis of a sample taken from a carload lot.

Weight, one gallon	16.08 pounds
Specific gravity	1.93
Percent As_2O_3	50.60
Percent NaOH	12.80
Pounds As_2O_3 per gallon	8.13
Pounds NaOH per gallon	1.96

This material is in the form of a heavy liquid, having the physical consistency of a thin syrup. In this condition it flows readily, hence the amounts used in the experiment were determined by liquid measure.

The company attempts to keep the percentage of white arsenic as constant as possible, and guarantees eight pounds to the gallon. Likewise the caustic soda content does not vary appreciably.

Methods of Experimentation

No present method of experimentation with grasshopper baits, developed to determine their relative efficiency, will give absolutely accurate data. The method used in this experiment is the most satisfactory one we have been able to devise thus far. We select an area for our plots which is isolated from outside infestation as much as possible, in the event that reinfestation seems a factor. Plots of from 2 to 8 acres in size are then taken, adjoining each other, so that the entire poisoned area is in a solid block.

Poison bran-mash is distributed by hand during the morning from 7 to 11 o'clock. Distribution is made by the same person and at the same rate per acre (about 8 pounds figured on the dry-bran content) on all of the plots.

Results are checked by sweeping. One person does all of the sweeping, taking care to do it in the same manner on all plots in order to minimize the factor of personal error. In the first experiment, five different sweepings of fifty strokes each were made, counts being recorded at the end of each. The first sweeping was made immediately after the poison was distributed, and the others at regular intervals thereafter. The sweepings were made inside of the inner half of the plot, and taken in all possible directions. Knowing that weather conditions would affect the number of 'hoppers swept from day to day, in so far as possible, after the first day, subsequent sweepings were made when the climatological data conformed as nearly as possible to that first recorded. In this manner, the percentage of kill was based on the actual infestation of each plot at the time of poisoning and at certain intervals thereafter.

THE FORT MORGAN EXPERIMENT

The series of grasshopper-bait experiments which first contained the sodium arsenite plots, were carried on in an alfalfa field under valley conditions at Fort Morgan, Colorado. The entire area contained 20 acres, which was cut longitudinally by a number of irrigation laterals, ¼ mile long. The spaces between laterals, known as lands, varied from 3 to 4 rods in width. The plots contained two of these lands in width, and one half the course of the laterals in length.

The alfalfa was mowed just previous to the experiment and in the center of each land, a strip 10 feet wide was left uncut. Also the weeds which had grown up on the ditch banks were left standing. In these two places the 'hoppers largely congregated, and here all sweepings were made.

The date the experiment began was July 8, 1922.

Only five of the nine baits tried out, are here given. The "wet mix", or the placing of the poison in the "soup", was used in all cases.

THE BAITS

PLOT NO. 1—KANSAS BAIT

Bran (free of shorts)	100 pounds
Crude white arsenic (98% As_2O_3)	5 pounds
Salt	5 pounds
Black-strap molasses	2 gallons
Lemons (finely ground)	2 dozen
Water	10 gallons
Time of application	7:15 to 7:30 a. m.

PLOT NO. 2—STANDARD BAIT

Bran (free of shorts)	100 pounds
Crude white arsenic (98% As_2O_3)	5 pounds
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of application	7:30 to 7:45 a. m.

PLOT NO. 7—COLORADO GRASSHOPPER BAIT NO. 10

Bran (free of shorts)	100 pounds
Sodium arsenite	2 quarts
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of application	8:45 to 9:00 a. m.

PLOT NO. 8—COLORADO GRASSHOPPER BAIT NO. 11

Bran (free of shorts)	100 pounds
Sodium arsenite	1 quart
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of application	9:00 to 9.15 a. m.

PLOT NO. 9—COLORADO GRASSHOPPER BAIT NO. 12

Bran (free of shorts) ..... 100 pounds
Sodium arsenite ..... 1 pint
Salt ..... 5 pounds
Sugar beet-refuse molasses ..... 2 gallons
Amyl acetate (Tech. No. 1) ..... 3 ounces
Water ..... 10 gallons
Time of application ..... 9:15 to 9:30 a. m.

SWEEPING DATA

Plot No.	Date 1922	SWEEPINGS 1	2	3	4	5	Total	P'c't Dead
1	7-8	75	59	44	66	43	287	0
2	7-8	70	50	66	59	72	317	0
7	7-8	100	124	225	130	142	721	0
8	7-8	77	104	106	235	350	872	0
9	7-8	230	220	200	219	245	1114	0
1	7-11	39	50	43	33	18	183	37
2	7-11	43	35	33	46	16	173	46
7	7-11	55	40	35	46	57	234	68
8	7-11	28	34	64	24	42	192	78
9	7-11	63	38	42	46	40	229	80
1	7-13	20	21	15	17	14	87	70
2	7-13	25	28	20	25	24	122	62
7	7-13	31	39	21	23	20	134	84
8	7-13	25	30	24	15	24	118	87
9	7-13	48	40	42	44	22	196	83

WEATHER DATA

Plot No.	Date 1922	Time of day A. M.	Temp. near ground Deg. F.	(1) Sky	(2) Wind	(3) Moisture	Remarks
1	7-8	9:30	102	Bright sun	Stiff breeze	Dry	Wind interfered
2	7-8	9:45	110	Bright sun	Stiff breeze	Dry	Wind interfered
7	7-8	10.40	110	Bright sun	Hard wind	Dry	Wind interfered
8	7-8	11:05	108	Cl'dy p't'ly	Hard wind	Dry	Wind interfered
9	7-8	10:55	110	Bright sun	Hard wind	Dry	Wind interfered
1	7-11	9:40	75	Cloudy	Stiff breeze	Dry	Hoppers not active
2	7-11	9:55	73	Cloudy	Stiff breeze	Dry	Hoppers not active
7	7-11	11:00	70	Cloudy	Stiff breeze	Sp'l'ng	Hoppers not active
8	7-11	10:30	76	Cloudy	Stiff breeze	Dry	Hoppers not active
9	7-11	10:45	70	Cloudy	Stiff breeze	Dry	Hoppers not active
1	7-13	9:00	80	Bright sun	Sl'gh breeze	Dry	
2	7-13	9:05	81	Bright sun	Still	Dry	
7	7-13	9:50	94	Bright sun	Still	Dry	
8	7-13	9:30	90	Bright sun	Sl'gh breeze	Dry	
9	7-13	9:40	92	Bright sun	Sl'gh breeze	Dry	

It will be noted from the foregoing data that on the day when applications were made, weather conditions were unfavorable for an optimum catch, due to the hard wind blowing. On the second date of sweeping, there was still a rather stiff breeze, but the weather was much cooler, making the catch larger than it should have been. Again on the third date of sweeping, an excess of 'hoppers was taken in comparison to the first day, due to the fact that either no wind, or only a slight breeze, was blowing. Thus, it seems that the percentage killed, based on the sweepings is low, or, at least, very conservative.

During the preparation of the baits, it was found that we had been furnished with one sack of mill-run bran, which was mixed for Plot No. 7 before the mistake was noticed. This may account for a lower percentage killed on this plot than on plot No. 8.

On July 10, no sweeping was made, due to the fact that it had rained during the previous night, and was still threatening storm. These conditions, compared with those on the first day of sweeping, would not have given a fair comparison.

LIVE HOPPERS AT BEGINNING OF EXPERIMENT

Melanoplus bivittatus (immature)	2,519
Melanoplus bivittatus (mature)	212
Melanoplus femur-rubrum	122
Melanoplus coccineipes	50
Melanoplus atlanis	35
Melanoplus packardii	17
Melanoplus differentialis	9
Total	2,964

DEAD HOPPERS AT CLOSE OF THE EXPERIMENT

Melanoplus bivittatus	640
Melanoplus atlanis	71
Melanoplus femur-rubrum	41
Melanoplus packardii	37
Melanoplus coccineipes	19
Spharagemon collare	6
Dahinia brevipes	3
Melanoplus differentialis	3
Dissostiera carolina	1
Total	821

This represents a collection of both the live and dead 'hoppers taken at random over the several plots, the only idea in mind being to obtain the relative percentage of species.

THE LIVERMORE EXPERIMENT

The second experiment was carried on under foothills conditions on dry pasture-land near Livermore, Colorado. Here

the infestation was not heavy, averaging from about 20 to 30 grasshoppers to the square yard. However, this was a sufficient number to prevent the valuable native buffalo and grama grasses from gaining any start, and the feed was extremely short.

The plots were all approximately seven acres in size, except No. 6, which was fourteen acres. The mash was sown at the rate of eight pounds per acre, figured on the dry-bran content.

Checking by sweeping was done in essentially the same manner as in the first experiment. One change was made to save time in the field. This was the preservation of the insects swept, in jars of 2 percent formalin, and countings made in the laboratory. To do this, a funnel-shaped net with an open bottom, was constructed. During operation, the open bottom was buttoned up against the side of the net.

Also, due to the light infestation, 400 strokes were made on each plot instead of the customary 250.

The experiment began August 16, 1922. At this time, practically all of the 'hoppers were in the adult stage.

THE BAITS

PLOT NO. 1—KANSAS BAIT

Bran (free of shorts)	100 pounds
Paris green	4 pounds
Salt	5 pounds
Lemons (finely ground)	2 dozen
Black-strap molasses	2 gallons
Water	10 gallons
Application	7:30 to 8:00 a. m.

PLOT NO. 2—STANDARD BAIT

Bran (free of shorts)	100 pounds
Crude white arsenic (98% As_2O_3)	5 pounds
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of application	8:00 to 8:25 a. m.

PLOT NO. 5—COLORADO GRASSHOPPER BAIT NO. 11

Bran (free of shorts)	100 pounds
Sodium arsenite	1 quart
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of Application	9:15 to 9:35 a. m.

PLOT NO. 6—COLORADO GRASSHOPPER BAIT NO. 12

Bran (free of shorts)	100 pounds
Sodium arsenite	1 pint
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of application	10:00 to 10:45 a. m.

PLOT NO. 7—COLORADO GRASSHOPPER BAIT NO. 13

Bran (free of shorts)	100 pounds
Sodium arsenite	½ pint
Salt	5 pounds
Sugar beet-refuse molasses	2 gallons
Amyl acetate (Tech. No. 1)	3 ounces
Water	10 gallons
Time of application	9:35 to 10:00 a. m.

SWEEPING DATA

Date of application—August 16, 1922

PLOT NO. 1

Species	Number
Ageneotettix scudderi Brun	33
Amphitornus bicolor Thom	17
Melanoplus packardii Scudd	11
Melanoplus bowditchi Scudd	10
Aulocara elliotti Thom	7
Hesperotettix viridis Thom	6
Melanoplus flabellifer Scudd	5
Melanoplus bivittatus Say	4
Mestobregma kiowa Thom	2
Oecanthus sp	1
Trimerotropis citrina Scudd	1
Total	97

PLOT NO. 2

Ageneotettix scudderi Brun	73
Melanoplus packardii Scudd	38
Amphitornus bicolor Thom	32
Melanoplus flabellifer Scudd	13
Melanoplus bowditchi Scudd	10
Aulocara elliotti Thom.	5
Melanoplus atlanis Riley	3
Oecanthus sp.	3
Trimerotropis citrina Scudd.	2
Hesperotettix viridis Thom.	1
Melanoplus bivittatus Say	1
Total	181

PLOT NO. 5

Melanoplus packardii Scudd.	72
Ageneotettix scudderi Brun.	43
Melanoplus atlanis Riley	31
Amphitornus bicolor Thom.	23
Melanoplus flabellifer Scudd.	10
Aulocara elliotti Thom.	8
Melanoplus bivittatus Say	5
Mestobregma kiowa Thom.	2
Oecanthus sp.	2
Arphia tenebrosa Scudd.	1
Melanoplus bowditchi Scudd.	1
Melanoplus coccineipes Scudd.	1
Metator pardalinus Sauss	1
Total	200

PLOT NO. 6

Ageneotettix scudderi Brun.	60
Melanoplus packardii Scudd.	43
Amphitornus bicolor Thom.	32
Melanoplus atlanis Riley	23
Melanoplus coccineipes Scudd.	12
Melanoplus bowditchi Scudd.	11
Melanoplus bivittatus Say.	6
Aulocara elliotti Thom.	5
Anabrus purpurascens Uhl	4
Hesperotettix viridis Thom.	3
Melanoplus flabellifer Scudd.	3
Oecanthus sp.	2
Acrolophitus hirtipes Say	1
Total	205

PLOT NO. 7

Ageneotettix scudderi Brun	84
Melanoplus packardii Scudd.	38
Amphitornus bicolor Thom.	20
Hesperotettix viridis Thom.	20
Melanoplus atlanis Riley	16
Melanoplus flabellifer Scudd.	10
Melanoplus coccineipes Scudd.	8
Melanoplus alpinus Brun.	5
Melanoplus bivittatus Say.	4
Spharagemon collare Scudd.	4
Aulocara elliotti Thom.	2
Oecanthus sp.	2
Melanoplus bowditchi Scudd.	1
Trimerotropis citrina Scudd.	1
Total	215

Three days after application—August 19, 1922.

PLOT NO. 1

Melanoplus packardii Scudd.	6	*Melanoplus coccineipes* Scudd ...	1
Ageneotettix scudderi Brun.	2		
Amphitornus bicolor Thom.	2	Total.....	13
Melanoplus atlanis Riley	2	Percent dead	86

PLOT NO. 2

Melanoplus coccineipes Scudd. ..	5	*Aulocara elliotti* Thom.	1
Amphitornus bicolor Thom.	3	*Melanoplus atlanis* Riley	1
Melanoplus flabellifer Scudd.	3		
Melanoplus packardii Scudd.	3	Total.....	17
Anabrus purpurascens Uhl.	1	Percent dead	90

PLOT NO. 5

Melanoplus packardii Scudd.	9	*Hesperotettix viridis* Thom.	1
Ageneotettix scudderi Brun.	3	*Melanoplus coccineipes* Scudd.	1
Melanoplus atlanis Riley	3		
Melanoplus flabellifer Scudd.	3	Total.....	22
Amphitornus bicolor Thom.	2	Percent dead	89

PLOT NO. 6

Ageneotettix scudderi Brun.	4	*Spharagemon collare* Scudd	1
Melanoplus coccineipes Scudd. ...	1		
		Total.....	6
		Percent dead	97

PLOT NO. 7

Ageneotettix scudderi Brun.	12	*Hesperotettix viridis* Thom.	2
Amphitornus bicolor Thom.	6	*Melanoplus coccineipes* Scudd. ...	2
Melanoplus atlanis Riley	4		
Melanoplus packardii Scudd.	3	Total	29
		Percent dead	86

Six days after application—August 22, 1922

PLOT NO. 1

Species	Number		
Melanoplus packardii Scudd.	3	*Ageneotettix scudderi* Brun	1
Amphitornus bicolor Thom.	2	Total	7
Acrolophitus hirtipes Say.	1	Percent dead	92

PLOT NO. 2

Melanoplus packardii Scudd.	5	*Ageneotettix scudderi* Brun.	1
Amphitornus bicolor Thom.	4	*Melanoplus atlanis* Riley	1
Melanoplus coccineipes Scudd. ..	4		
Acrolophitus hirtipes Say.	1	Total	16
		Percent dead	91

PLOT NO. 5

Melanoplus packardii Scudd.	11	*Hesperotettix viridis* Thom.	1
Melanoplus atlanis Riley	7		
Amphitornus bicolor Thom.	2	Total	21
		Percent dead	89

PLOT NO. 6

Melanoplus packardii Scudd	4	*Melanoplus bivittatus* Say.	1
Ageneotettix scudderi Brun.	3	*Melanoplus bowditchi* Scudd.	1
Hesperotettix viridis Thom.	2		
Amphitornus bicolor Thom.	1	Total	13
Aulocara elliotti Thom.	1	Percent dead	93

PLOT NO. 7

Melanoplus packardii Scudd.	12	*Aulocara elliotti* Thom.	1
Amphitornus bicolor Thom.	9	*Hesperotettix viridis* Thom.	1
Ageneotettix scudderi Brun.	7	*Melanoplus flabellifer* Scudd.	1
Melanoplus coccineipes Scudd.	3		
Melanoplus atlanis Riley	2	Total	38
Melanoplus bivittatus Say.	2	Percent dead	82

WEATHER DATA

Plot No.	Date 1922	Time of day	Temp.	Sky	Wind	Moisture	Remarks
1	8-16	10:15 a. m.	Very hot	Clear	Stiff breeze	Dry	
2	8-16	10:30 a. m.	Very hot	Clear	Stiff breeze	Dry	
5	8-16	11:15 a. m.	Very hot	Clear	Sl'gt breeze	Dry	
6	8-16	12:00 m.	Very hot	Clear	Stiff breeze	Dry	
7	8-16	11:45 a. m.	Very hot	Clear	Stiff breeze	Dry	
1	8-19	10:30 a. m.	Hot	Clear	Sl'gt breeze	Dry	Light Shower previous p. m.
2	8-19	10:45 a. m.	Hot	Clear	Sl'gt breeze	Dry	Light shower previous p. m.
5	8-19	11:30 a. m.	Hot	Clear	Sl'gt breeze	Dry	Light shower previous p. m.
6	8-19	12:15 p. m.	Hot	Clear	Sl'gt breeze	Dry	Light shower previous p. m.
7	8-19	12:00 m.	Hot	Clear	Sl'gt breeze	Dry	Light shower previous p. m.
SODIUM ARSENATE—— FOUR							
1	8-22	10:15 a. m.	Hot	Clear	Stiff breeze	Ground damp	Heavy rain previous p.m.
2	8-22	10:30 a. m.	Hot	Clear	Stiff breeze	Ground damp	Heavy rain previous p.m.
5	8-22	11:15 a. m.	Hot	Clear	Stiff breeze	Ground damp	Heavy rain previous p.m.
6	8-22	12:00 m.	Hot	Clear	Stiff breeze	Ground damp	Heavy rain previous p.m.
7	8-22	11:45 a. m.	Hot	P'r'tly cloudy	Stiff breeze	Ground damp	Heavy rain previous p.m.

RESULTS

The results of both of these experiments indicate that sodium arsenite used in the strength of one pint to 100 pounds of dry bran, is fully as effective as either the Kansas bait or the standard formula, carrying five pounds of 98 percent crude white arsenic. Likewise, it seems to be practically as effective as the Kansas bait containing four pounds of Paris green to the hun-

dred pounds of dry bran. In the second experiment, one half pint of sodium arsenite to one hundred pounds of dry bran gave good results, yet there was a noticeable decrease in the killing power in comparison to the other formulae. If the infestation had been greater and each individual 'hopper had had access to less bait, perhaps this weaker strength would have given much poorer results. From the present data, it would seem that one pint of sodium arsenite to one hundred pounds of dry bran is the optimum strength of the poison to use.

THE OPTIMUM AMOUNTS OF POISON

Practically all of our grasshopper bait formulae carrying crude white arsenic require five pounds of this material for one hundred pounds of bran. This seems to be accepted by entomologists as the standard strength. Experimentation by Ford and Larrimer of the U. S. Bureau of Entomology substantiates this belief (3). They summarize by saying:

"The optimum strengths for the three standard poisons were found to be: Paris green, ½ lb.; white arsenic, ¾ lb.; and crude arsenic, 1½ lbs., per each 25 pounds of bran."

One pint of sodium arsenite contains 1.01 pounds of As_2O_3. Although no experimental data are available to explain the reason such a small amount of this arsenical is needed, yet it can possibly be accounted for in two ways. First, a considerably more even distribution of the poison throughout the mash insures a maximum poisoning power for each and every flake of bran. Second, due to the complete solubility of this poison, it is more readily digested and assimilated by the insect, than are other poisons used, thus making its killing power more efficient.

THE ADVANTAGES OF SODIUM ARSENITE

The requisites of the killing agent in bran mash may be summarized as follows:

It must kill effectively; mix evenly through the mash; be cheap enough to make its use practical; be comparatively safe to use; and must be readily available on the market.

Mixing

When white arsenic is mixed properly, the sodium arsenite has no advantage over it in killing value. However, from the standpoint of mixing, the sodium arsenite is as nearly "fool proof" as any chemical can be. Its entire solubility in cold water means that all particles of water carry exactly the same amount of poison, and that every flake of bran which is moistened is also poisoned. From the standpoint of the field worker, who must depend upon farmers to do the mixing of the mash, this seems to be the superior property of sodium arsenite over the so-called "standard poisons."

COST

The cost of poison materials f.o.b. Fort Collins, upon which this experiment was based, was as follows:

Material	Amount	Amount of bran in lbs.	Equivalent of As_2O_3 in lbs.	Percent of As_2O_3 per cwt. of bran	Cost per cwt of bran
Paris green	2 lbs.	100	1	1	$0.70
As_2O_3	5 lbs.	100	5	5	0.45
$Na(AsO_2)_2$	2 qts.	100	4	4	0.70
$Na(AsO_2)_2$	1 qt.	100	2	2	0.35
$Na(AsO_2)_2$	1 pint	100	1	1	0.175
$Na(AsO_2)_2$	½ pint	100	½	½	0.0875

Thus the cost of the optimum amount of sodium arsenite is less than half that of white arsenic, and only one-fourth that of Paris green.

POISONING OF MIXERS

The canned grasshopper baits being developed in recent years mark an important step of progress in grasshopper control. Realizing the advantage of having a prepared bait to supply to farmers suffering from isolated, local outbreaks of locusts where no actual entomological assistance in the field could be given, the State Entomologist of Colorado, in co-operation with the State Experiment Station and the Extension Service, put up, during the past season, a canned preparation known as "Colorado Poison Grasshopper Paste." The formula for this was as follows:

White arsenic 98 percent..... 5 pounds
Salt . . .. 5 pounds
Amyl acetate (Tech. No. 1) ..... 3 ounces
Water . . .. 2 quarts

This amount of material was placed in a one-gallon can and sold to the farmers. The sale approximated two thousand cans, even though much of it went out to small outbreaks.

The season's experience pointed out the fact that white arsenic is extremely dangerous to the mixers of the bait, due to the dust, though all known precautions to prevent poisoning were taken. This was the strongest point distinctly against the continued use of the canned poison. Sodium arsenite, being liquid, completely does away with this danger.

CANNED BAIT

For use in a canned bait, the sodium arsenite has other advantages over white arsenic. It will greatly reduce the bulk of material needed, thus cheapening the containers used, and likewise the transportation of the finished product to the consumer. It will also minimize the overhead expense of mixing, because it is easier to handle and measure than the white arsenic.

AVAILABILITY

As previously stated, owing to the development of commercial sodium arsenite as a weed killer, this product is rapidly being placed on all the large markets. It apparently will be only a matter of a short time until it will be available from small chemical concerns and drug stores. At the present time, it is nearly as readily obtained in large quantities as white arsenic.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance of Mr. R. H. Sims, County Pest Inspector of Morgan County, who aided greatly in carrying on the experiment at Fort Morgan, and of Mr. Ernest Roberts, on whose ranch the Livermore experiment was made. To Professor W. F. Schlupp, Entomologist of the School of Agriculture and Experiment Station, Potchefatroom, Transvaal, Union of South Africa, he is indebted for information concerning the use of sodium arsenite in South Africa.

SUMMARY

1. White arsenic is often an unsatisfactory killing agent in poison bran-mash, due to imperfect mixing.

2. Sodium arsenite has been used in South Africa since 1894, as the killing agent in liquid poison baits.

3. These experiments indicate the possibility of the use of one pint of commercial sodium arsenite containing 50 percent As_2O_3, to replace the present dosage of 5 pounds of white arsenic per 100 pounds of bran.

4. As a killing agent in poison bran-mash, sodium arsenite has advantages over white arsenic in mixing, cost, handling, in use in canned baits, and is fully as efficient.

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METHODS OF HANDLING HAY IN COLORADO

By G. A. CUMINGS



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METHODS OF HANDLING HAY IN COLORADO

By G. A. CUMINGS

Hay is extensively grown in every section of Colorado where sufficient moisture is available, and is necessarily handled under a wide range of conditions. The quality of hay is determined almost entirely at the time of stacking, which means that organization and efficiency are of supreme importance to the hay grower.

The purpose of this bulletin is to describe, in a general way, the common and successful methods of curing, stacking and protecting hay in the State of Colorado.

Several kinds of hay are grown but alfalfa is the principal one and unless special reference is made to a particular kind, alfalfa will be the one under discussion.

Averages taken from a large number of estimates are given for the State as a whole, and should be considered as only approximate when applied to specific cases.

IMPORTANCE OF THE HAY CROP IN COLORADO

According to the Fourteenth census of the United States (1920) the acreage and value of hay exceeds those of any other crop grown in Colorado. Approximately 1,600,000 acres or 32 percent of the crop area of the State is given to hay, the value of which is 38 percent of the value of all other crops combined.

The various kinds of hay grown in Colorado are, in the order of their acreages: Alfalfa, wild or native hay, green grains, mixed timothy and clover, millet, timothy, sudan grass, sweet clover, field peas and clover. Other kinds of hay are grown but not to any great extent. Hay is grown at elevations from 3,500 to 8,000 feet, on all kinds of soil and under a wide range of climatic conditions.

The hay crop, even under the more favorable conditions found in Colorado at the time of making hay, requires more constant attention and efficient handling than other crops. Cutting and stacking are limited to a comparatively short period of time if done without a material loss of quality and quantity of hay. Any delay in stacking operations is very costly; the valuable time of a large stacking crew is lost; tons of hay may be lost by shattering, leaching, extra handling and difficulty in raking, especially if enough time has elapsed for the next crop to get started; the hay is of inferior quality because of the bleaching, loss of leaves, and improper curing.

The successful hay grower must possess unusual ability. He must be able to plan his work, organize his crew, exercise good judgment, come to quick decisions in case of unfavorable

weather or accidents and, above all, he must be able to handle large crews of men.

TIME OF CUTTING

The stage of maturity at which alfalfa hay should be cut is indicated in two principal ways: First, when new shoots are well started at the crown of the plant. Later cutting gives a decrease in yield, woody and less palatable hay, and, by clipping off the new shoots, retards the next crop. Secondly, from the time bloom first appears until one-half in bloom is considered the best time to cut. Wild or native hay is cut from the time it blooms until ripe, green grains in the milk or dough stage, mixed timothy and clover when the timothy reaches second color of bloom, millet in the milk stage, timothy in second bloom for horses and earlier for cattle, Sudan grass in full bloom, sweet clover at first bloom or before, field peas when most of the pods are ripe, and clover in full bloom.

IRRIGATING BEFORE CUTTING

When hay is irrigated to start the next crop it should be done at least three or four days before cutting. If sufficient time is not allowed for the ground to become firm, difficulties will be experienced in mowing, the draft of all machinery will be greatly increased, the ground will be marked by deep wheel tracks and hoof prints, and there will be more time required and uncertainty in proper curing.



Fig. 1. Two-horse mowers cutting second crop alfalfa hay.

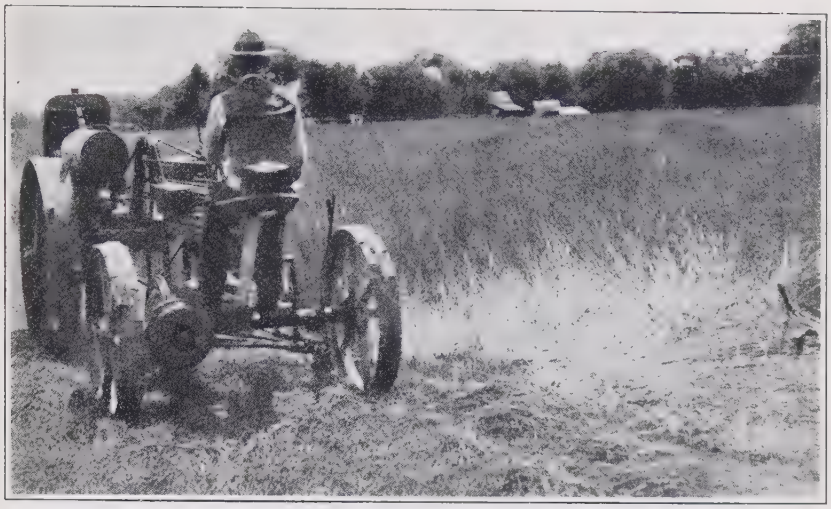


Fig. 2. A tractor mower in operation.

MOWING

On the larger hay ranches mowing is almost a continuous operation from the time cutting starts until the close of the haying season. From one to six mowers are operated depending upon the acreage, yield, and size of crew. Since moisture does not materially injure newly mown hay, it is not always advisable to discontinue mowing during unfavorable weather where hay is liable to ripen too much or a large acreage must be handled. Hay is easier to handle and cure when cut in favorable weather.

Mowers.—The mower with a five-foot cutter bar is the one most commonly used. Compared with wide-cut mowers, it is light, has less draft and is more convenient to handle along fences and ditches. The 6-foot and 8-foot two-horse mowers, and 8-foot and 10-foot tractor mowers are coming into more general use. Figure 1 shows two-horse mowers in operation.

The wide-cut mowers are particularly adapted to large ranches where the stand of hay is not heavy enough to give excessive draft for an average team. Tractor mowers are of interest only to the man who uses a tractor for other farm work. They have been used successfully where labor is scarce or the acreage is large. By using a two-horse mower in connection with a tractor mower to mark out ditches, cut along fences and finish lands, very large acreages are cut per day. A tractor mowing outfit is shown in Figure 2.

Mower Troubles, Care and Repair.—The common mower troubles are: Heavy draft, worn and loose parts, non-centering

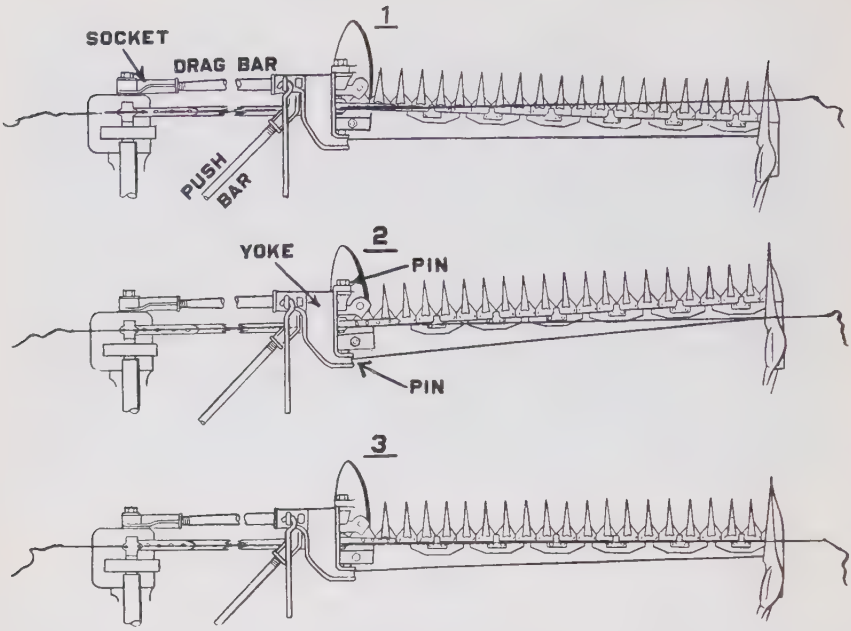


Fig. 3. Cutter bar alignment. Numbers 1 and 2 show non-alignment of cutter bar, number 3 shows a cutter bar properly aligned. (Reprint from the Farm Implement News, Chicago.)

of sickle, non-alignment of cutter bar, broken pawls, dull or broken sickles, dull ledger plates and gummed cutter bars.

The remedies for worn clips or wearing plates, loose sections, loose bearings, broken pawls, dull sickles or ledger plates, broken sickles and bent guards will not be discussed for they should be obvious to the hay grower. Heavy draft is usually caused by poor lubrication, dull sickle, and non-alignment. Non-alignment of a cutter bar is often overlooked by the farmer. It is caused by wear of the yoke pins which allows the end of the cutter bar to fall back out of line with the pitman. A string stretched along the center line of the pitman should fall on similar points along a properly aligned cutter bar. (See Figure 3.) When no adjustments are provided, the cutter bar may be aligned by properly bushing around the yoke pins. The ordinary adjustment on the drag bar is not intended to align the cutter bar and if wrongly used as such, produces another serious trouble of non-centering of the sickle without correcting the non-alignment.

The sickle is centering or registering when the sections stop in the center of the guards at either end of the stroke. Non-centering, as shown in Figure 4, would leave strips of grass uncut. The drag bar or pitman adjustments are used to center

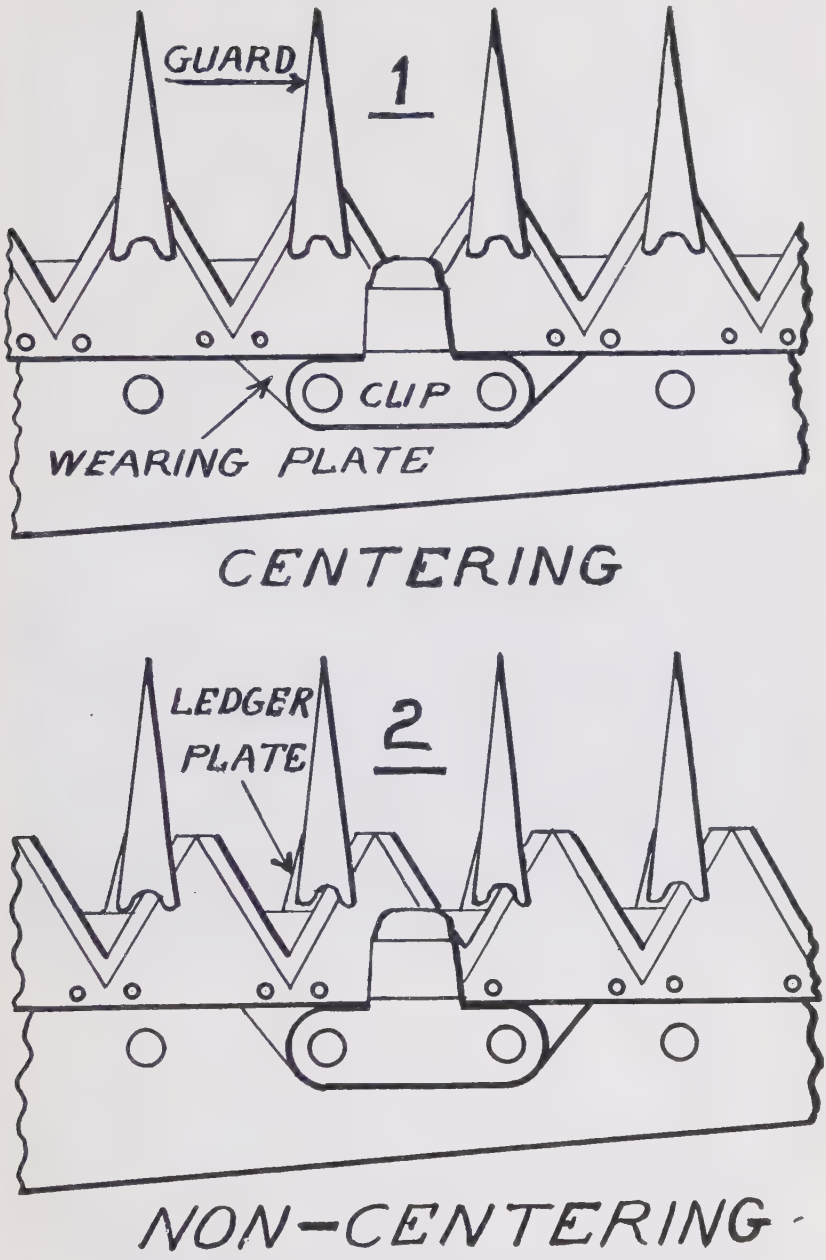


Fig. 4. Centering and non-centering of sickle.

the sickle. Sickle sections ground to a point are liable to leave strips of grass uncut.

Heavy gum on the parts of the cutter bar is formed under certain conditions by the mixture of oil and grass juices. Water poured on the cutter bar will tend to remove the gum. When gum interferes to any extent, oil should not be used on parts of the cutter bar kept moist by grass juices.

Excessive side-draft is a good indication of an improperly adjusted cutter bar.

CURING HAY

The method of curing hay depends upon the kind of hay, quality of hay desired, use of hay and climatic conditions. Practically all of the hay is cured either in the swath and windrow or in the cock. Frequently timothy hay and grasses are cured in the swath, and alfalfa is partly cured in the stack.



Fig. 5. Curing hay in the windrow. Windrows permit a free circulation of air thru the hay and prevent excessive bleaching.

Curing Hay In the Swath and Windrow.—A majority of the hay growers, stacking on a large scale, allow the hay to lie in the swath until wilted, then rake it into windrows with sulky or side-delivery rakes, where curing is completed. Hay raked into windrows allows a free circulation of air which rapidly carries away the moisture given off by the leaves. (Figure 5.) This method is faster, requires less labor, and gives a good quality of hay, compared with the other methods of curing. The time between cutting and raking will depend upon the stage of maturity and weather conditions, but a better quality of hay will be secured if most of the curing is done in the windrow

rather than the swath. From 3 to 7 days are required to cure hay in the windrow.

Hay, which has been partly cured in the windrow, is often bunched with a sulky rake, thus loosening it up and insuring thoro curing, as well as simplifying the work of the sweep rake. Bunching hay in this sense is not cocking but simply a second raking, as shown in Figure 6. Since less hay is exposed when bunched, there will be less bleaching and shattering provided the hay is bunched before it gets too dry. In case of rain, bunched hay does not dry out readily, but is considered to be of better quality if allowed to dry out well before turning.



Fig. 6. Bunching hay with a sulky rake to hasten curing and reduce bleaching.

Curing Hay In the Cock.—In sections of the State where weather conditions interfere with curing or where a superior quality of hay is desired, hay is cured in cocks. As soon after cutting as the hay is free from any surface moisture it is raked and piled into cocks, as shown in Figure 7. Smaller cocks of 100 pounds or less are preferred. From 5 to 10 days are required for the hay to cure, depending upon existing conditions. Hand labor is necessary in building cocks and pitching hay out of cocks, making this the slower and more expensive method. Hay cannot be satisfactorily handled on a large scale where so much time and hand labor are required in curing, consequently this method is not used on the largest ranches.

Hay cured in the cock is of a superior quality, containing little bleached hay and retaining a bright green color. Since a much greater percentage of the leaves, the most nutritious part of the plant, is also saved, the hay makes a more palatable and valuable feed.



Fig. 7. Curing hay in cocks reduces bleaching to a minimum and prevents damage by rain.

Curing Hay In the Swath.—Timothy hay and grasses are sometimes cured in the swath, when the weather is not too hot. Where the yield is heavy, as in parts of Routt County, a tedder may be used to loosen up the hay. Curing is seldom completed in the swath. The advantages of curing hay in the swath are: (1) The hay will dry out faster in case of rain. (2) Timothy and grasses do not permit as free circulation of air through windrows as alfalfa, and will cure faster in the swath. Disadvantages of curing hay in the swath are: (1) Hay gets too dry and bleached on top before it is properly cured below. (2) The methods of stacking hay make it necessary to rake the hay into windrows, which results in shattering and loss of hay if it is cured before being raked. (3) Uneven curing, bleaching and shattering produce poor quality hay.

Curing Hay In the Stack.—It is a common practice among sheep and cattle feeders to stack a part of their hay before it is entirely cured. It has been the experience of the most prominent hay growers to stack green hay directly from the mower without damage. Hay partly cured in the stack produces an immense amount of heat which gives the hay a dark brown color. Such hay is called "stack-burnt." It is not advisable to stack hay too green for it becomes dangerously hot and may be damaged.

"Stack-burnt" hay is recommended for sheep or cattle but not for horses. The effects of "stack-burnt" hay are similar to those of green grass in the spring. It is a change of feed and the animals eat more of it. The feeding value is no greater than that of other hay, but sheep and cattle relish it more and by eating larger quantities, temporarily at least, gain more in weight and milk production.

CURED HAY

An experienced hay grower has no difficulty in determining when hay is cured. By handling the hay he can tell, by the odor, touch and sound whether or not it is cured. The stems are the last part of the plant to cure and tests should be made on them. Hay is cured when: (1) Twisting a wisp does not bring out any moisture, (2) the stems appear dry and will break, (3) the hay feels dry, and makes a rattling noise when handled.



Fig. 8. Self-dumping sulky rake, a necessary machine for hay making.

RAKES

Sulky and Side-Delivery Rakes.— The sulky rake is universally used and an indispensable machine for hay making. (See Figures 6 and 8.) The side-delivery rake is used to an advantage by a large number of hay growers. At least one sulky rake is used in connection with side-delivery rakes to rake along ditches and bunch the hay. Figure 9 shows a side delivery rake in operation.

The advantages claimed for the side-delivery rake are: (1) More economy since both side-delivery rakes and sweep rakes may be operated lengthwise of the field. (2) It makes a straight clean-cut windrow. (3) Hay is left in a better condition for



Fig. 9. Side-delivery rake, which has replaced the sulky rake for the major part of the work.

curing. (4) It is most convenient when used with hay loaders, and (5) handy for turning windrows. The disadvantages of the side-delivery rake are: (1) It tends to "rope" hay, especially tough hay. (2) Sweep rakes have more difficulty in taking hay from the windrow. (3) It is impossible to rake close to ditches with the side-delivery rake.



Fig. 10. A typical sweep rake loaded with hay. (Courtesy of the International Harvester Company of America.)

Sweep Rakes.—Figure 10 shows a typical sweep rake loaded



Fig. 11. Sweep rake loading an overshot stacker. Where large quantities of hay are handled an extra push by the sweep rake is necessary to satisfactorily load the stacker.

with hay. Many kinds of sweep rakes are on the market and used by hay growers in this State. The three- and four-wheel, rear hitch power or horse-lift rakes are most commonly used.

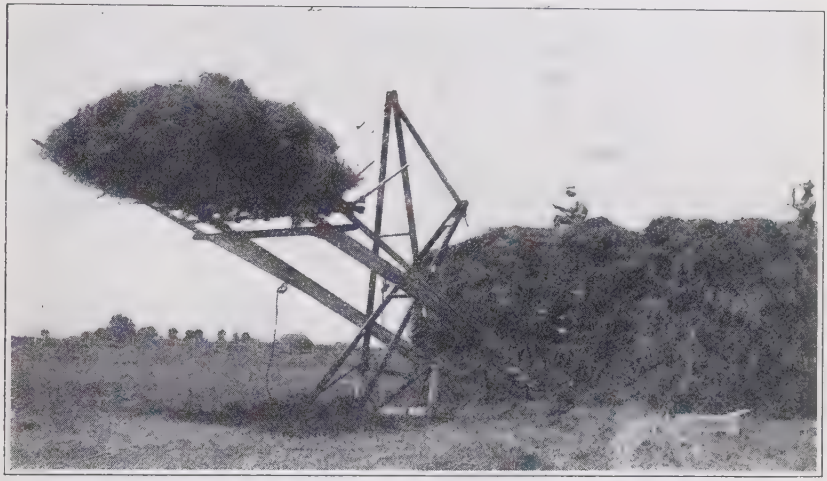


Fig. 12. Operation of the overshot stacker.

METHODS OF STACKING HAY

Many different kinds of stackers are used in Colorado, but practically all of the hay is stacked with one of five general types, namely: Overshot, swinging, combination, derrick and slide. The unique situation in the North Park region, where the slide is the only stacker used, will be taken up under slide stackers.

While the location of a ranch, acreage of hay, method of irrigation, climatic conditions, number and age of children, kind and amount of hired labor, kind of hay, use of hay, and initial cost of machinery are determining factors in the choice of a stacker, the stacker is usually chosen by personal preference of the hay grower. All



Fig. 13. Overshot stacker delivering hay to the stack. This stacker has adjustable arms and may be shortened for starting a stack.

the common stackers are used and adapted to the various conditions found in each section of the State.

Overshot Stackers.—The overshot stacker is used in every hay section of the State except the North Park region, and in greater numbers than any other type of stacker. It is light, easily moved, does satisfactory work, is cheaper than most patent stackers and is built by many manufacturers in various forms and sizes. Figures 11 to 16 inclusive show several types of overshot stackers.

The main objection to this type, as with other patent stackers, is the lightness which, under the heavy loads and strains, results in breakage and delay at critical times during the stacking period.

Stacks may be built as high as 26 feet but 20 feet is the average height.

Figures 11, 12, 13 and 14 show very clearly the principle upon which overshot stackers operate. The hay is carried directly over the stacker proper, and deposited on the center of the stack. Stop ropes, attached to compression springs, relieve the stacker of excessive strains when the stacker head is stopped in its delivery position. Sweep rakes cannot load stackers of this type with large quantities of hay without giving the hay an extra push, as shown in Figure 11. From one to four men are required to distribute the hay, depending upon the number of sweep rakes, length of haul, and size of stack, but seldom over two are necessary.



Fig. 14. A non-adjustable overshot stacker delivering hay to a newly started stack. Note the unnecessary height to which the hay is carried.

While the overshot stacker insures a stack with a firm center, the kind of stack built depends upon the condition of the hay, efficiency of the men on the stack, and the time given to distribute the hay.

The maximum capacity is no doubt greater than that of any other stacker except the slide, due to the shorter time required to operate it. The maximum capacity is of no advantage to the average crew since hay is not hauled

in fast enough to keep the stacker in continual operation. An efficient crew can stack about 4.5 tons per man per day.

With large crews the capacity of the stacker is often increased by giving the stacker a quicker action. The system of pulleys is replaced by a cable on a double drum horse-driven hoist. As the hay is delivered to the stack, the cable is detached from the stacker team, and the man operating the hoist immediately lowers the stacker head by means of a brake. The stacker is loaded by the time the stacker team has returned. Although an extra man is required to operate the hoist, the maximum capacity of the stacker is greatly increased.

One or more adjustments are usually found on overshot

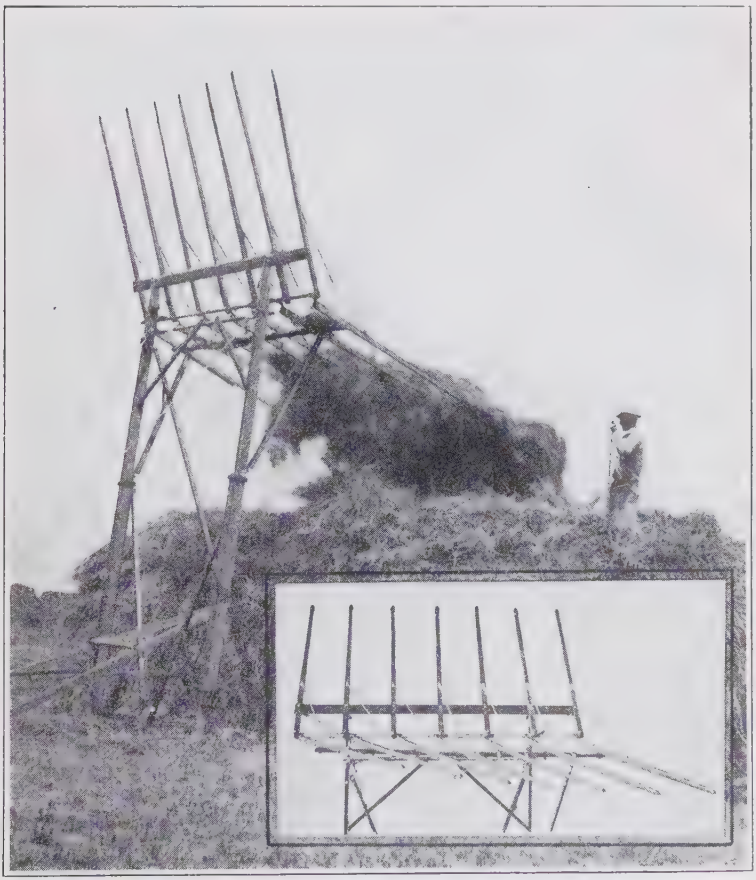


Fig. 15. An automatic overshot stacker which allows the hay to slide off the delivery teeth several feet to either side of center. (Insert, courtesy of The Superior Hay Stacker Company.)

stackers. The length of arms may be changed to correspond to the height of stack. Non-adjustable stackers are simpler and stronger but they carry hay to an unnecessary height with more difficulty in wind when the stack is low, and are not compact for storing or transporting. Figures 13 and 14 show adjustable and non-adjustable stackers delivering hay to a newly started stack.

Adjustments essential on a stacker with non-adjustable arms, are: Changing vertical angle of delivery teeth and length of stop ropes. By raising the delivery teeth or lengthening the stop ropes by changing the position of the compression springs, the hay is deposited on the center of the stack as the height of stack increases.

An adjustment recently introduced, changes the horizontal angle of the delivery teeth, which throws the hay several feet to either side of center. Due to the principle of operation, the hay slides off the teeth instead of being thrown off. Figure 15 shows a stacker of this type. Note the angle of the delivery teeth, as the hay is delivered.



Fig. 16. A type of overshot stacker mounted on wagon trucks for convenience in moving.

The crews operating overshot stackers investigated in the preparation of this bulletin varied in size from 3 men and 3 horses to 16 men and 26 horses. The most common sizes of crews are from 6 to 9 men, which are most efficient. Large or small crews are used as circumstances demand but usually the larger crews are inefficient by having a man or machine idle a part of the time. The 4- and 5-men crews are efficient crews on smaller acreages where all of the stacking operations are not continually carried on. Typical crews are shown in the following table:

TABLE I. Stacking Crews used with Overshot Stackers.

Entire Crew		**Arrangement of Crew									
		Stack	Sweep rakes		Stacker team		Stk'r Op'tr	*Side-Delivery rakes, Sulky rakes & Mowers		Relief	
Men	Horses	Men	Men	Horses	Men	Horses	Men	Men	Horses	Men	Horses
3	3	1	1	2	1	1	0	‡(1)	(2)		
3	4	1	1	2	1	2	0	‡(2)	(4)		
4	6	1	2	4	1	2	0	‡(3)	(6)		
5	6	2	2	4	1	2	0	‡(3)	(6)		
6	6	2	2	4	1	2	1	‡(3)	(6)		
6	8	2	2	4	1	2	0	* 1	2		
7	8	2	2	4	1	2	1	* 1	2		
7	10	2	2	4	1	2	0	* 2	4		
8	10	2	3	6	1	2	1	* 1	2		
8	12	2	2	4	1	2	0	3	6		
8	12	2	3	6	1	2	0	* 2	4		
9	12	2	3	6	1	2	1	* 2	4		
9	14	2	3	6	1	2	0	3	6		
10	14	2	3	6	1	2	1	3	6		
12	16	3	3	6	1	2	1	4	8		
16	26	4	4	8	1	2	1	6	12	0	4
16	26	(2	3	6	1	2	0	2	4)		
Divided		(2	3	6	1	2	0	2	4)	0	2

* Mowing and raking are not always continuous operations and the men and horses may be shifted from one machine to another.

‡ Numbers in parentheses represent men and horses used on other parts of the crew.

** Arrangements of crews other than those mentioned in the table are used under exceptional circumstances.

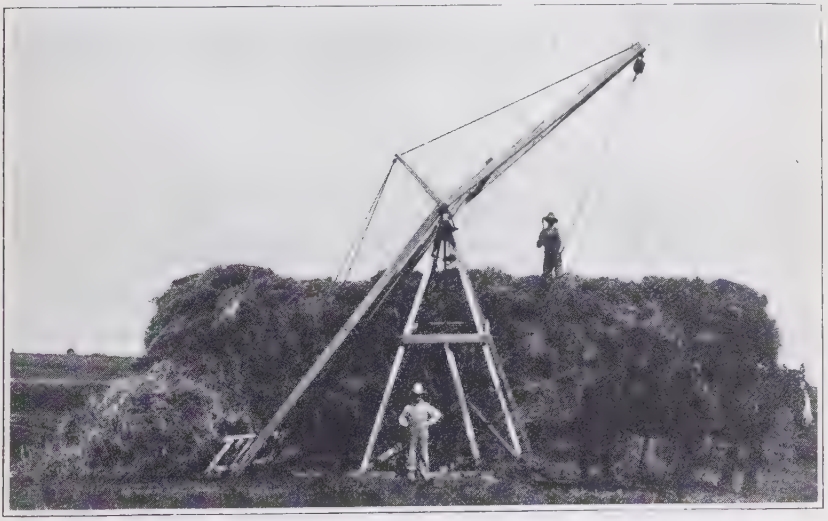


Fig. 17. An automatic swinging stacker with the head loaded and the trip set to deliver the hay at a predetermined point on the stack.



Fig. 18. An automatic swinging stacker in operation. This stacker may be loaded from either side.

Swinging Stackers.—The swinging stacker which in many ways is similar to the overshot, is built in several forms and sizes. The swinging stacker is necessarily a little more complicated in construction than the overshot stacker but is not subject to any more difficulties. It is extensively used and does very satisfactory work. It is built light and convenient and is subject to breakage under heavy strains.

Notwithstanding the fact that certain parts of most patent stackers are built too light and weak, breakage is often due to carelessness on the part of the stacking crew. The stacker may



Fig. 19. A swinging stacker delivering hay after being automatically tripped. The weight of the hay tilts the stacker for delivery.

be loaded too heavily, the stacker team driven carelessly, or the repair of weak parts neglected.

The average height of stack built is about 20 feet, with a maximum height of about 26 feet.

Figures 17, 18 and 19 show very clearly the operation of a swinging stacker. The hay is carried to the height of the stack, swung around and dropped at any desired point on the stack. Unlike the common overshot stacker the hay slides off the teeth instead of being thrown off. Figure 18 shows a stacker which may be loaded at either side and also the manner in which the hay is delivered. Stackers loaded from either side may be



Fig. 20. Hand controlled swinging stacker with which the operator can accurately place the hay on the stack. (Courtesy of The International Harvester Company of America.)

loaded on the side most convenient for the sweep rakes, which gives less difficulty in case of a strong wind, or nearest the stacker head when it is tripped.

Delivering hay where it is desired greatly reduces the labor on the stack and to such an extent that sometimes the men get careless in distributing the hay which permits moisture to readily penetrate the stack.

The average number of men employed on the stack for overshot stackers is 1.8, for swinging stackers 1.3, which indicates that in many instances one less man is required on the stack.

Adjustments on swinging stackers are conveniently made for height of elevation and time of delivery.

Swinging stackers may be either hand controlled or automatic. Hand-controlled stackers are swung (with the aid of the stacker team) and tripped by the operator. Hay is accurately placed which greatly reduces labor on the stack. Figure 20 shows a hand-controlled swinging stacker.

Automatic swinging stackers mechanically elevate, swing, and trip the stacker head. (See Figure 19.) The stacker-team driver sets the trip to deliver the hay at any predetermined point in the circle of the stacker. Altho the hay may not be as accurately placed as with the hand-controlled stacker, the operator is eliminated.

Hay is stacked at an average rate of 4.3 tons per man per day which is practically the same as for overshot stackers. The maximum capacity which is seldom reached is no doubt less than that of the overshot stacker. Double drum hoists are used to increase the maximum capacity and eliminate a system of ropes and pulleys.

The size of crew is the same as those given in Table 1, page 17, with the exception of the number of men on the stack. As previously mentioned in this discussion, frequently one less man is required on the stack.

Combination Rake and Stacker.—The combination rake and stacker, sometimes known as a portable stacker, altho less used than the stackers previously discussed, is found in nearly every hay section of the State. Since the hay may be delivered at any point of elevation, this stacker is not built in a number of different sizes. It is light compared with other stackers but when it must be pulled thru any great distance, more work is required of the stacker team than with other stackers. The amount of work placed on the stacker team tends to limit the size or height of elevation of the combination stacker. Some stackers elevate the hay about 23 feet but the average height of stack is not over 18 feet.

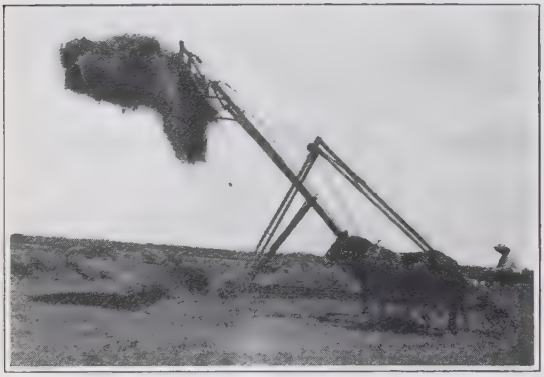


Fig. 21. A combination rake and stacker which will load itself and elevate the hay as it approaches the stack. The stacker head has been elevated and locked in position for transporting.

The combination stacker can be used as either a sweep rake or

a stacker. It is self loaded from windrows or loaded by sweep rakes. (See Figures 21, 22, and 23.) The stacker head is elevated by a cable drum on the main axle and can be locked at any desired height by engaging a ratchet or brake and releasing the clutch. By the further aid of a steering wheel in the rear and a delivery trip, the stacker is under positive control of the operator. Hay is delivered to the stack by tilting the stacker head and allowing the hay to slide off. After the hay has been delivered, the lowering of the stacker head assists the horses in backing the stacker, altho the stacker head may be lowered independently by the operator. A medium weight or heavy team is necessary to successfully operate the combination stacker.



Fig. 22. A sweep rake loading a combination stacker.

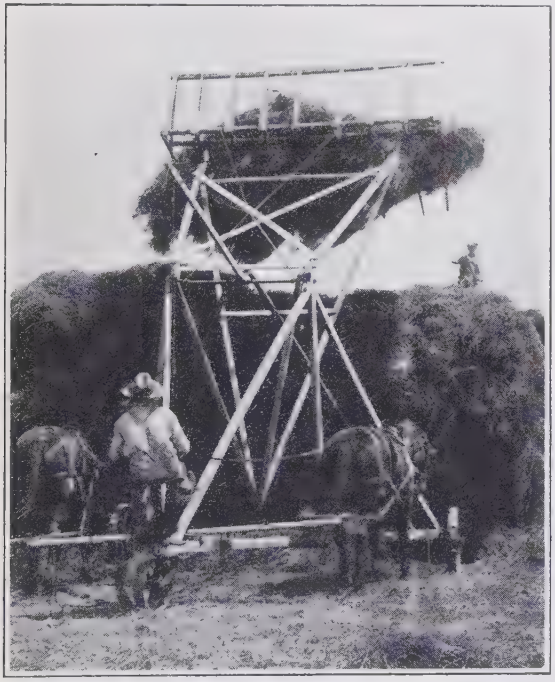


Fig. 23. A combination stacker delivering hay to the stack. Hay can be delivered to any point on the stack which greatly reduces labor on the stack.

Sweep rakes could be eliminated by loading the stacker from windrows but the machine is too large and heavy to be pulled through any great distance. The most common method of loading the stacker with small crews, is to deposit the hay with sweep rakes in



Fig. 24. Loading a sling carried by a "slip" which eliminates any unnecessary height of pitching.

bunches near the stack, and self load the stacker as desired. As shown in Figure 23, the stacker conveniently approaches the stack at any point, thus reducing labor on the stack to a minimum. Large crews usually load the stacker directly from sweep rakes as shown in Figure 22. The stacker is used only on one



Fig. 25. A sling carefully loaded by the pitchers greatly reduces labor on the stack.

side of the stack and backed far enough each time to allow room for the sweep rakes to unload and to enable the stacker to elevate the hay to the desired height when advancing towards the stack.

The capacity is the same as that of swinging stackers. The average amount of hay stacked per man per day is about 4.3 tons for large crews and 4.7 for small crews, showing a greater efficiency than other stackers for small crews.

The size of the crew employed when the stacker is loaded directly from the sweep rake, is the same as those mentioned in Table 1, Page 17, except frequently one less man is used on the stack. Combination stackers have a great advantage with small crews. For instance with a crew of 2 men and 4 horses, both men mow and rake until a quantity of hay has been deposited in bunches near the stack, then raking is discontinued while one man operates the stacker and the other stacks the hay. With a three-man crew, one man drives a sweep rake, another the stacker and the third stacks the hay.

Derrick Stackers.—The derrick stacker has been used in every hay section of Colorado, including the North Park region. However, it has been abandoned in North Park, because of the superiority of the slide stacker. The derrick is a home-made stacker, consequently is built in many forms and sizes as may be noted in the accompanying Figures. Slings or forks are used with derrick stackers. The Mormon type of derrick stacker is the one most commonly used and is built very strong and heavy, making it reliable but inconvenient to move. (See Figure 26.) Very large and high stacks are built with derrick stackers. The height of stack is usually not over 30 feet, altho the stacker is built any reasonable height which the hay grower might prefer.



Fig. 26. A Mormon type of derrick stacker requiring two teams to move it.

When using a derrick stacker the hay is generally cured in cocks, as explained on page 9, then pitched

by hand onto "slips"* or wagons and hauled to the stacker. "Slips" eliminate any unnecessary height of pitching and a man to load them, as shown in Figures 24 and 25. Slings are usually preferred to forks for they handle hay in large quantities without any shattering or scattering and deposit the hay on the stack in the same condition as it is placed on the sling. Therefore a large part of the labor in stacking is done by the pitchers who use care in loading the slings. Note in Figure 27 how the man on the stack does most of the stacking by properly locating the sling before it is tripped. Figure 27 also shows the operation of a derrick stacker using slings and "slips." Figure 28 shows the operation of a pole type of derrick stacker using wagons and a fork. It is a satisfactory method of handling hay but very slow compared to other methods. Figure 29 shows a derrick stacker using wagons and slings. Wagons are not often used unless the hay must be hauled a considerable distance. By having the lower pulley, located off center a few feet, the pull of the horses

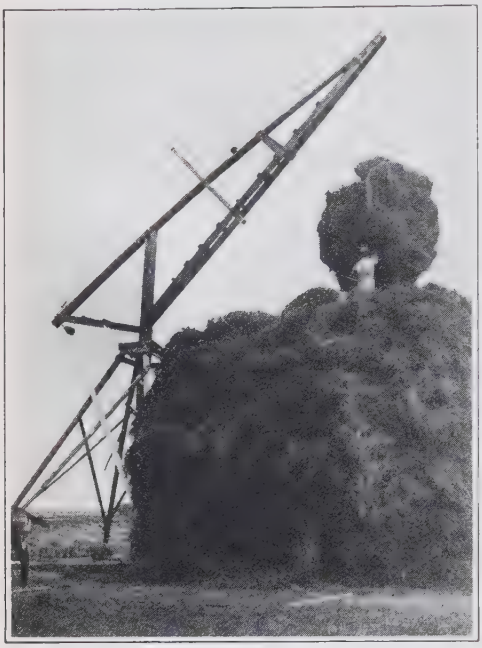


Fig. 27. The sling is properly located before it is tripped. The derrick stacker shown in this figure is a very substantial Mormon type.



Fig. 28. A pole type of derrick stacker, using wagons and a fork. A slow method of stacking hay.

* "Slip" is the term used among hay growers for a flat door-like skid about 6 feet by 12 feet which carries a sling.

swings the boom over the stack. The "slip" driver pulls the sling and boom back into a starting position with the trip rope.

The Wilson type of derrick stacker is similar to the Mormon type in its principle of operation and construction but much lighter in weight. As shown in Figure 30, the stacker is supported by a light base and three guys. It has two adjustments for raising or extending the boom, which are conveniently made. The Wilson type of derrick stacker is not used to any great extent because the Mormon type is more simple and durable.

In a few instances, on the larger ranches, sweep rakes are used with derrick stackers. Hay is cured in the windrow and hauled to the stacker on sweep rakes. A large sling, sunk flush with or a little below the surface of the ground, receives the hay and carries it onto the stack. The only advantage of this method is the reduction of hay losses by building large, high stacks.

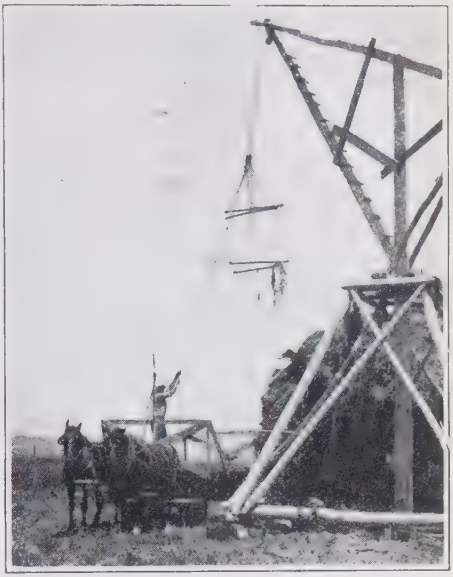


Fig. 29. Derrick stacker with wagons and slings. Wagons are used when hay must be hauled long distances.

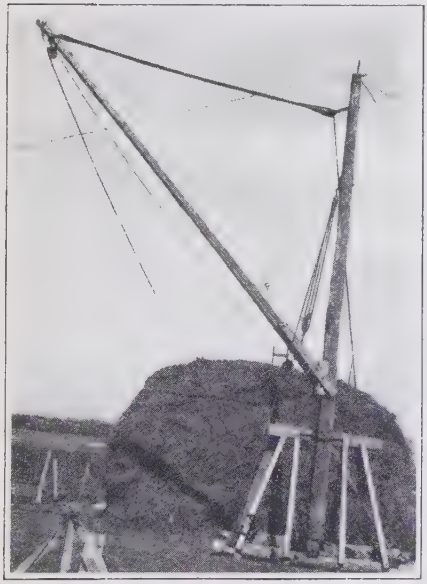


Fig. 30. Wilson type of derrick stacker which is light and readily adjusted.

Conditions under which the derrick stackers are best adapted are: (1) On small ranches where native timber is accessible, (2) Where hay growers desire large, well-built stacks and the best quality hay, (3) Where climatic conditions are such as to require special care in curing and stacking to preserve the hay, (4) Where topography

or type of irrigation interfere with the operations of sweep rakes, (5) Where hay must be hauled some distance to the stack, and (6) Where a small investment is essential.

The amount of hay stacked per man per day is about 3.1 tons which is only two-thirds as much as stacked with an overshot stacker.

The size of crew employed to operate derrick stackers varies with the amount of hay to be stacked. The size of the average crew is small, since derricks are not found on the larger ranches. The following table gives typical stacking crews for derrick stackers.

TABLE 2. Stacking Crews used with derrick stackers.

Entire Crew		Arrangement of Crew					
		Stack	Slips		Stacker Team		Extra Pitchers
Men	Horses	Men	Men	Horses	Men	Horses	Men
2	4	1	(2)	(4)	1	2	0
3	4	1	(2)	(4)	1	2	1
4	4	1	2	4	(1)	(2)	1
5	6	1	2	4	1	2	1
5	6	1	3	6	(1)	(2)	1
6	8	1	3	6	1	2	1
7	8	2	3	6	1	2	1
8	8	2	3	6	1	2	2
9	10	2	4	8	1	2	2

a. Figures in parentheses represent the same men or horses as on other parts of the crew.

b. Mowing, raking and cocking are usually done by the same men who pitch and stack the hay.

c. When wagons are used, several extra pitchers are necessary.



Fig. 31. A sweep rake depositing hay at the base of a typical slide stacker. Little time and care are required compared with the same operation with overshot stackrs.



Fig. 32. The pusher collects the hay and carries it over the stacker. Long rollers are used on the pusher to reduce friction.

Slide Stackers.—The slide stacker is practically the only stacker used in North Park and surrounding territory because of the unique situation in those regions. Similar stackers are occasionally used in other parts of the State but are exceptional cases. The slide is a home-made stacker and is built in several forms and sizes. Height of stacks ranges from 16 to 20 feet.

Figures 31, 32 and 33 show the operation of the slide stack-



Fig. 33. Hay being delivered to the center of the stack by a slide stacker. Driving the pusher team fast or slow throws the hay to either side of the stack.

er. The hay is deposited by sweep rakes at the base of the stacker, then carried over the stacker by the pusher. Very little time, care, and accuracy are required in depositing hay at the stacker, compared to loading other types of stackers. If hay is slightly scattered when deposited at the stacker, the pusher has no difficulty in collecting it. By driving the pusher team fast or slow the hay may be thrown to either side of the stack. To return the pusher, it is carried back part of the way by its own weight, then the team is turned across the pusher pole, the double-trees turning on a swivel, and the pusher pulled back into a starting position. Two men are necessary on the stack even where labor is reduced by building stacks in sections.

The capacity of a slide stacker is about 10 tons per hour. The amount of hay stacked per man per day is about 6.9 tons, altho when eliminating mowing and raking, as high as 15 tons per man per day are stacked near Steamboat Springs where the yield is exceptionally heavy. The greater capacity and efficiency of the slide stacker are due to the following reasons: (1) Native hay is not bulky like alfalfa and can be conveniently handled in large quantities. (2) Sweep rakes need not make an extra push to load the stacker as is often the case with other stackers. (3) Less care may be exercised in handling native hay without danger of shattering. (4) Stack cribs are built to prevent waste by cattle, which assist greatly in building stacks. (5) The cooler climate enables a man or team to do more work.

The ordinary slide stacker has no adjustments except the

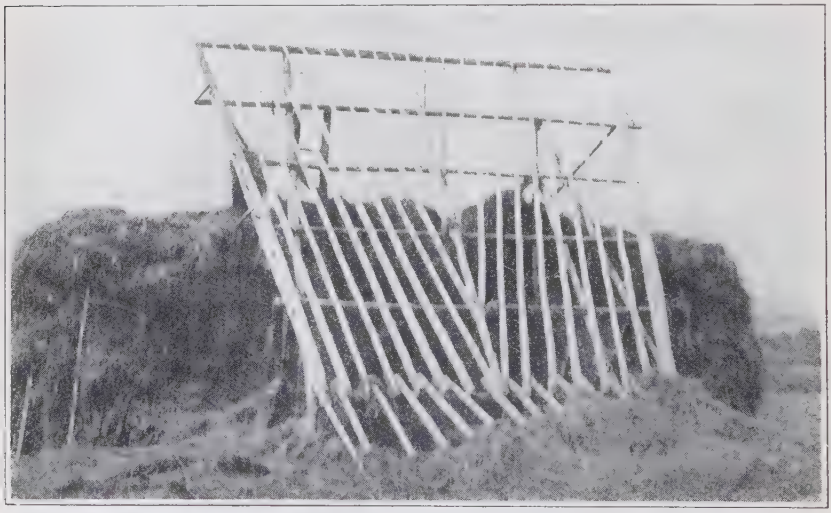


Fig. 34. A fan-shape stacker designed to carry the hay to either end of the stack.

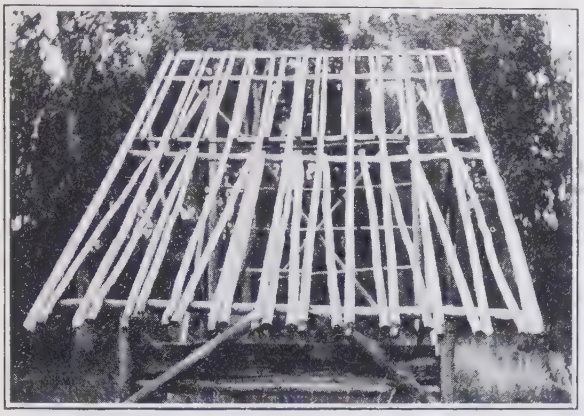


Fig. 35. A slide stacker with adjustable upper and lower aprons. The lower apron swings over and back to the ground, the upper apron slides upward as the height of stack increases.

lower apron may be turned up for transporting. Figure 34 shows a fan-shaped stacker designed to deliver the hay towards either end of the stack. The fan-shaped stacker is not entirely successful for the hay tends to follow the poles regardless of the direction the pusher is traveling. Figure 35 shows a stacker with an adjustable lower apron for transporting and an adjustable upper apron for extension as the height of stack increases.

Patent sweep rakes are used with slide stackers where the hay land is cultivated and smooth, but they are not strong enough to carry the heavy loads over rough ground, as is often found in North Park. Figure 36 shows the home-made North Park sweep rake. It has only two wheels, short teeth and is very heavily constructed. The rake is balanced by the operator who shifts his weight along the plank or platform extending to the rear.

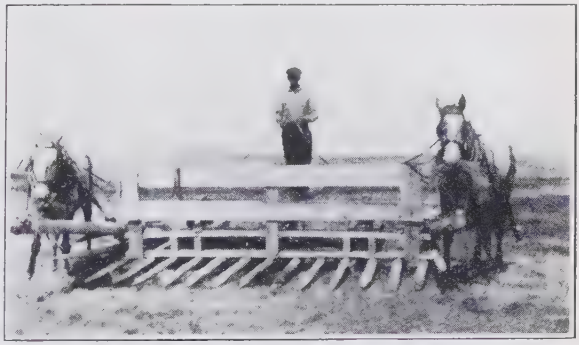


Fig. 36. The home-made North Park sweep rake. Note the heavy, substantial construction which is necessary to stand the heavy strains.

The size and arrangement of crews where the slide stacker is used are similar to those given in Table 1, under overshot stackers, except a man is not used to operate the stacker. Where the hay is light and the acreage is large, as many as 6 mowers are run continuously thruout the haying season, with one man spending his entire time grinding sickles. A typical crew on

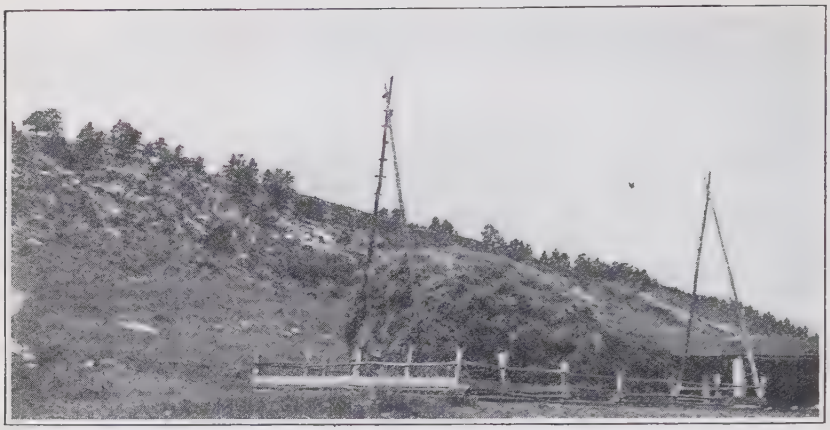


Fig. 37. A cable stacker held in place by guys.

large hay ranches of 2,000 acres consists of 17 men and 30 horses —2 men on the stack, 3 men and 6 horses on sweep rakes, 1 man and 2 horses on the pusher, 4 men and 8 horses on sulky rakes. 6 men and 12 horses on mowers, 1 man as sickle grinder, and 2 relief horses.

Cable Stackers.—Cable stackers are used only on small ranches where the stack site is permanent near the barn or feed-lots. Figure 37 illustrates clearly the construction and operation of the stacker. The stacker is home-made and inexpensive. Either forks or slings are used. Very large stacks are built, insuring small losses.

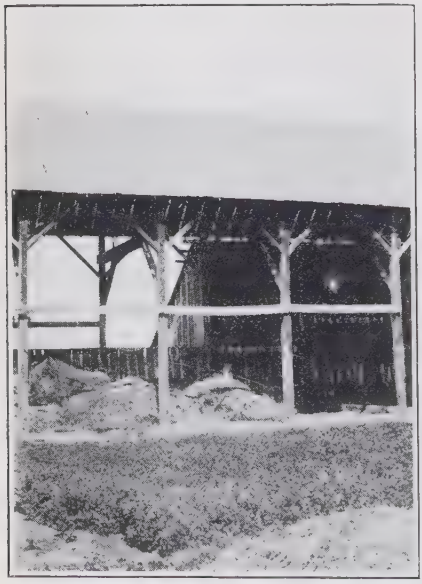


Fig. 38. A section of a typical hay shed used in the southwestern section of Colorado.

Hay Sheds.—Hay sheds are used principally in La Plata county where very heavy rains and snows are common. Figure 38 shows a section of a typical hay shed. They are expensive and necessitate long hauls, but without them a large percentage of the hay would be lost in certain localities. Hay sheds are built sufficiently large to hold most of the hay, produced on the ranch, the size of the shed

varying in length rather than width or height. Sheds are commonly boarded up several feet at the bottom forming a crib for the hay and protection against cattle and horses.

The size of the crew is the same as those mentioned under derrick stackers, page 26. Either forks or slings may be used but slings are preferred. The hay is carried on a track from the middle or end of the shed. Where the hay is loaded on wagons, hay loaders can be advantageously used. Assuming the same length of haul, more hay can be stacked in hay sheds than can be stacked by derricks, due to less labor or care in loading the slings and stacking the hay.

Hay sheds must be well constructed to withstand the heavy rains, snows and winds. They cannot be used profitably except under extreme climatic conditions, as will be discussed under "Protection of Hay."

Rope Stackers.—Rope stackers, although nearly replaced by modern stackers, are still used to some extent in the extreme southwestern section of the State. The stacker itself is simple, light, and convenient to move, but apparently a crude method of stacking hay.

Figure 39 represents the principle upon which the rope stacker operates. The hay is rolled onto the stack and may be deposited at any desired point. The amount of labor on the stack depends very much upon the condition of the hay. A special sling is carried on "Slips" or wagons. No adjustments are necessary with this stacker.

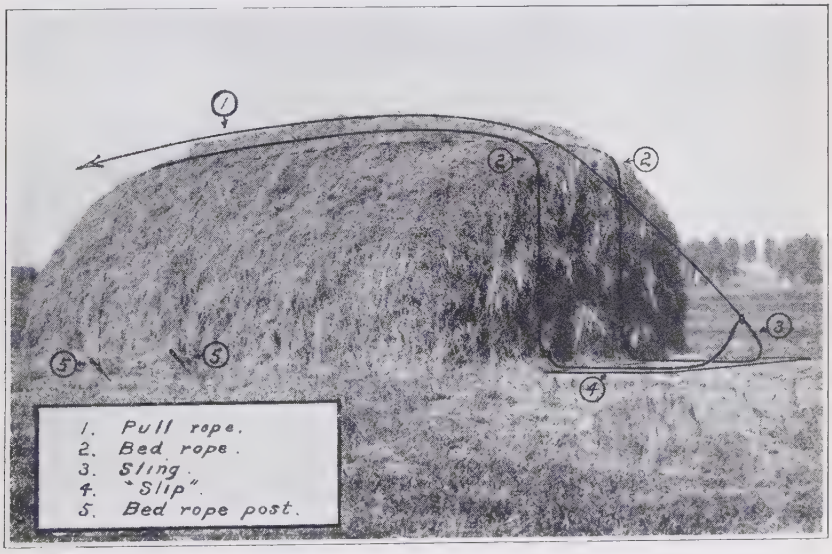


Fig. 39. The principle upon which the rope stacker operates.

The rate at which hay may be stacked is about the same as for derrick stackers. Hay growers who have used the rope stacker, think it is a satisfactory method of stacking hay, but it is too slow. The size and arrangements of crews are similar to those given in Table 2, page 26.

Baling Hay From the Windrow or Cock.—Baling hay from the windrow or cock is practiced to some extent in a few sections of the State. Baling does not interest the man who feeds his hay or sells to alfalfa mills, but eliminates stacking for the man who exports or transports his hay. Figure 40 shows a modern power hay press in operation.



Fig. 40. A power hay-press for baling hay from the windrow, cock, or stack. (Courtesy of The International Harvester Company of America.)

In order to successfully bale hay from the windrow, the climatic conditions must be favorable. If hay is not thoroly cured it is liable to heat or spoil. If it must be exposed long before thoroly dry, a percentage of the hay will be bleached or sun-burned. The rate at which hay may be baled from the windrow is 2.5 to 3.5 tons per man per day, which, being less than that handled by patent stackers, limits the use of the baler to a great extent. Successful baling of hay insures good quality, small losses and a saving of labor.

Baling hay from the stack is a very common practice and necessary in transporting hay any distance. Where a hay grower bales a part or all of his hay from the stack, he should investigate the possibilities of baling from the windrow which would be a great saving of labor and expense.

An efficient baling crew consists of 6 to 8 men—2 men on

sweep rakes, 2 pitchers, 1 feeder, 2 wirers and 1 off-bearer. Modern power presses have automatic feeders and block droppers which increase the capacity and reduce hand labor.

Care and Storage of Baled Hay.—Great care should be exercised in keeping bales dry in the field. If they are not hauled to the storage shed every day, they should be protected by some suitable covering such as loose hay or canvass. An emergency canvass or tarpaulin should be carried at all times, to be used in case of sudden rains.

Hay baled from the windrow should be stored in a manner which permits the circulation of air. Bales piled on edge a couple of inches apart with alternate layers crosswise insures a circulation of air through the entire pile, and greatly lessens the danger of heating.

Hauling Hay Direct To Alfalfa Mills.—Hay growers near an alfalfa mill haul all or a part of their hay to the mill, directly from the windrow or cock, thus eliminating stacking operations. While this is a great saving of labor it can affect only a few hay growers; the alfalfa mill has a limited capacity and cannot handle hay on a large scale and hay growers living some distance from the mill cannot spend the extra time for hauling during the haying season.

Blower Stackers.—A blower stacker has been detached from a grain separator and used successfully as a hay stacker in timothy hay, and mixed timothy and clover hay. (Figure 41.) This stacker has been operated in the vicinity of Colorado Springs



Fig. 41. A blower stacker stacking timothy hay. A crew of two men, two horses, and a tractor stacking hay at the rate of 1.8 tons per hour. (6 tons per man per day is the average rate of stacking hay with the blower stacker.) No men on the stack, no stacker team or driver, and no stacker operator.

for 3 years with no damage to stacks by wind or rain. Since the stacker is power driven, and no men are required on the stack, the number of men on the stacking crew is greatly reduced.

Hay is hauled to the stacker with sweep rakes, and pitched by hand into a funnel-shaped feeder. The automatic rotating device on the stacker distributes the hay. Stacks of about 20 tons are built. The amount of hay stacked per day is about 6 tons per man for a 3-man crew. The initial cost of such a stacker, with a source of power, and its possible shattering effects on alfalfa hay, would prohibit its general usage under present labor conditions.

Stacking By Hand.—Stacking by hand is a very slow, laborious method and used only where the amount of hay is too small to justify any investment in hay machinery. It is used in orchards and other places inaccessible by modern hay machinery.

INTRODUCTION OF MECHANICAL POWER

Mechanical power has been successfully applied to a few hay stacking operations, but has not been used to any great extent. The flexibility required in hay machinery and the cheapness of labor, under present conditions, do not offer much encouragement for the use of power machinery except in a few instances.

Balers.—Perhaps the most successful appliance of mechanical power has been with hay balers. (See Figure 40.) Power balers are used extensively in Colorado but not at the time of making hay, as discussed under "Baling from the Windrow", page 32. The advantages of power balers when compared with horse balers are: Continuous operation regardless of hot weath-

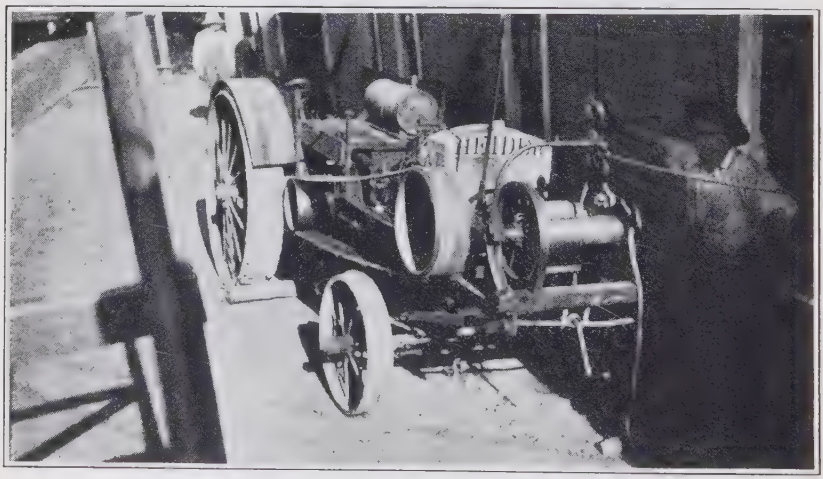


Fig. 42. A double drum power hoist.

er, higher capacity, less space required, and more economical per ton baled.

Hoists.—Power hoists are used to some extent; they eliminate the stacker team and operate the stacker or carrier faster than horses do. (See Figures 42 and 43.) Hay growers prefer horses to power hoists for the following reasons: (1) Horses are more flexible and reliable. (2) They operate the stacker as rapidly as desired by most crews. (3) It takes a capable man to successfully operate engine hoists but any child can drive a team. (4) The initial cost of a power hoist is greater. Power hoists are used to advantage with large crews who keep the stacker in continual operation or where horse labor is scarce.



Fig. 43. A power hoist operating the carrier in a hay shed.

Mowers.—Tractor mowers are used successfully on large ranches where tractors are used for other farm work, and have been quite advantageously used when labor was scarce. There is a greater saving of labor where one man can operate the outfit. The operation of tractor mowers has been discontinued almost entirely under present conditions, because of the drop in price of horse feed and the cheaper labor available for running horse mowers. See discussion of wide-cut mowers, page 5.

Other Hay Machinery.—Mechanical power has been used on sweep rakes in an experimental way, but, to the knowledge of this department, not on sulky rakes, side-delivery rakes, hay loaders, "slips", wagons, or tedders.

ORGANIZATION AND MANAGEMENT OF CREWS

Both organization and management are controlling factors of the efficiency of a hay-stacking crew. Some crews stack only 50 percent as much hay as other crews of the same size, using similar machinery. Other factors which may affect the average

rate of stacking hay are: Kind of hay, yield of hay, length of haul, character of the land, climatic conditions, number of women or children, labor available, condition of machinery, care in stacking, and attitude of men. In general, crews are apparently well organized and managed for the conditions under which they work.

Inefficiency of capable crews is usually due to poor management. One man may retard the work of the whole crew; too much time may be taken at meal time or when some minor part breaks on a machine; men get to talking and arguing; the crew may be unbalanced, having some of the men idle a part of the time; or indifferent attitude of men and lack of "push" of the foreman may be causes of inefficiency.

PROTECTION OF HAY IN THE STACK

A thoro investigation has been made by this department in regard to hay losses and the feasibility of stack covers. The principal object of this investigation was to find an economical method of protecting hay in the stack, in order to meet the demands for good-quality hay, receive the higher prices offered for such hay, prevent losses, and to use less labor and care in stacking.

Hay Losses.—The percentage of hay lost without protection varies in different localities from 1 to 25 percent. The average loss for the entire State is about 7 percent as taken from a large number of estimates and personal observation. Important hay sections sustaining heaviest losses are La Plata and Morgan counties, and the southern part of Weld County. The feeding value of spoiled or discolored hay was not considered. Spoiled hay was assumed to be worthless. Heavy losses are due mainly to climatic conditions, but many times to insufficient care in stacking which is often admitted by the hay growers. Stacks in which the hay is poorly distributed and packed, absorb a large amount of moisture even after they are partly settled. Stacks with firm centers, hay well distributed and packed, and properly finished, will not absorb much moisture after standing a short time.

The importance of hay losses was brought forcibly to the attention of hay growers when prices of hay ranged from $20 to $35 per ton. Under normal conditions when average prices of hay are from $10 to $12 per ton, the farmer is not so vitally concerned about any expenditure to protect his hay.

Feasibility of Permanent Stack Covers.—Several types of permanent, demountable stack covers were designed with interchangeable sections, to be assembled on a stack of any length. The cost of painted corrugated iron, galvanized corrugated iron, and wooden covers were closely estimated and under 1922 prices vary from $85 to $109 for a 15-ton stack. Interest on investment

and depreciation give a yearly cost of $14.60 to $18.40 per 15-ton stack, to save a $12.50 loss of hay. Thus under present Colorado conditions, permanent stack covers are impractical except in a few extreme cases where hay sheds have been built.

Natural Means of Protection.—Some natural means of protecting hay in the stack are:

1. A covering of green hay, which holds its leaves, cures, packs closely and sheds much moisture.
2. A covering of slough grass or other heavy grasses which shed rain.
3. Special care in building stacks, keeping center full, hay well scattered and packed, and a full, round top.
4. Finishing the stack by raking off loose hay, smoothing sides and combing the stems downward allowing easy drainage of moisture.

In sections where rains are common during the stacking season, a canvass or tarpaulin should be carried as an emergency cover for open stacks.

RULES FOR MEASURING HAY

The measurement of hay in stacks cannot be done accurately because of the variations in the shape of stacks and the weight per unit of volume. The rule universally used and apparently quite accurate, is the U. S. Department of Agriculture rule quoted from circular No. 67:

$$\text{Volume} = F \times O \times W \times L$$

where F represents a fraction varying from .25 to .37, depending upon the shape of the stack as shown in Figure 44, O the over measurement or distance over the stack from the base on each side, W the average width, and L the average length.

To find the volume of a stack in cubic feet, first determine the value of F by comparing the shape of the stack to the cross-section in Figure 44. If the cross section of the stack is between two shapes given in the figure, an intermediate value of F may be used. Multiply the chosen value of F by the Over in feet, that product by the width in feet and the last product by the length in feet.

To find the number of tons of hay in a stack, divide the volume by the number of cubic feet per ton. The following table gives an approximate number of cubic feet of hay per ton after settling under Colorado conditions.

30 days	560 cubic feet per ton
60 days	540 cubic feet per ton
90 days	512 cubic feet per ton
120 days	485 cubic feet per ton
Late winter	450 cubic feet per ton

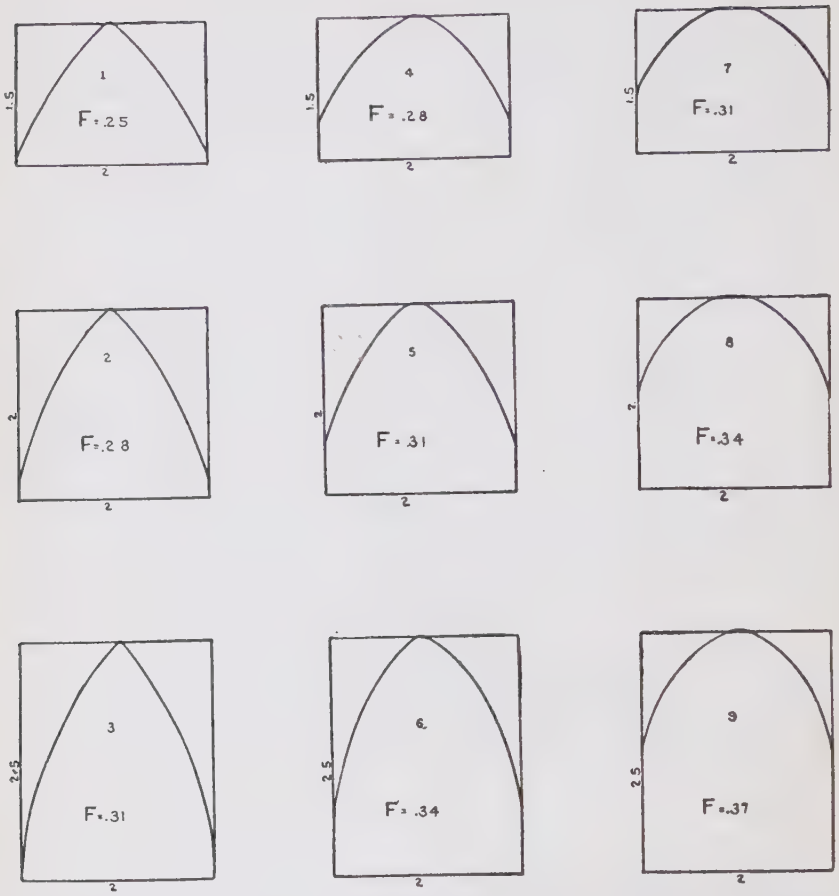


Fig. 44. Cross sections of different shaped hay ricks and the corresponding fraction (F) to be used in the formula for volume. (Reprinted from Circular No. 67. U. S. Department of Agriculture.)

Native hay packs together more closely than any other hay and 422 cubic feet of it is considered a ton.

The kind of hay and conditions at the time of stacking may produce slight variations in the figures given in the above table.

Example: A hay rick is 20 feet wide, 36 feet long and the over is 40 feet. The end view indicates that the shape of the rick is very close to No. 4, Figure 44. If the rick has settled for 60 days, how many tons of hay does it contain?

Solution: Volume = .28 x 40 x 20 x 36 = 8,064 cubic feet
Volume ÷ cubic feet per ton = No. of tons
8,064 ÷ 540 = 14.9 Tons of hay in the rick.

SUMMARY

Hay is the most valuable crop grown in Colorado and gives the farmer the most uncertainty in proper harvesting. Alfalfa is the principle kind of hay and should be cut at the beginning of bloom or when new shoots appear at the crown. Irrigating should be done a sufficient number of days before cutting to allow the ground to become firm.

Curing hay in the swath and windrow is a fast method, produces good-quality hay and requires little labor. Curing in the cock is slow and expensive but produces a superior quality of hay. Curing in the swath is not practiced except in timothy hay or grasses in cool, dry weather. Curing in the stack, if partly cured before, produces a palatable hay for sheep or cattle, known as "stack-burnt" hay. Hay is cured if moisture does not appear when a wisp is twisted in the hands.

A comparison of the methods of stacking hay indicates: The overshot stacker is extensively used, light, fast, builds stacks with firm, full centers, but requires much labor on the stack. The swinging stacker is similar to the overshot except labor is reduced on the stack and stacker but there is more liability of building stacks less resistant to water. The combination is best adapted to small crews, greatly reduces labor on the stack and stacker, approaches any side of the stack, but has a low limit of elevation, is heavy for an average team and more liable to build stacks less resistant to water. The derrick is cheap, heavy, slow, builds large stacks and insures good-quality hay. The slide is cheap and has the highest capacity but is adapted only to conditions similar to those found around North Park. Cable stackers, hay sheds, rope stackers, baling from the windrow or cock, hauling direct to alfalfa mills, blower and hand methods are used only under particular conditions. Mechanical power has been introduced successfully into baling, hoisting, and mowing under conditions favorable for each.

Hay losses are comparatively small in the State as a whole and permanent stack covers are not practical except in extreme cases.

Rules for measuring hay give only approximate results and vary greatly on different shaped stacks.

Bulletin 282 January, 1923

The Agricultural Experiment Station
OF THE
Colorado Agricultural College
Engineering Division

HEAT TRANSMISSION OF COMMERCIAL WALLBOARD

By G. A. CUMINGS

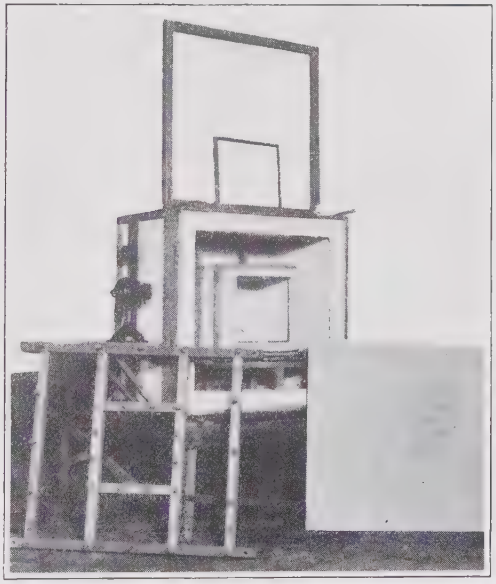


FIGURE 1.—Heat transmission test box, showing clamping frame, test specimen, and arrangement of boxes.

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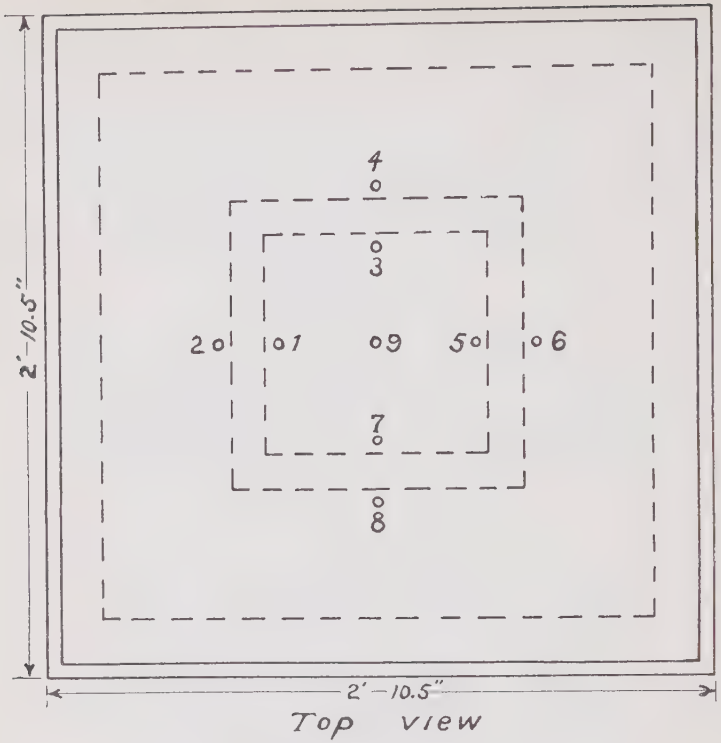


FIGURE 2. Location of thermometers and heating elements.

HEAT TRANSMISSION *of* COMMERCIAL WALLBOARD

By G. A. Cumings

Commercial wallboard has been extensively used during recent years in the construction of temporary buildings. It looks well, is easily handled, and requires little labor and skill in its application. Information on coefficients of heat transmission of wallboard has not been published, making it impossible to compare the value of wallboard with that of other types of wall construction as a heat insulator.

The object of these investigations is to determine approximately the rates at which heat is transmitted through the leading makes of commercial wallboards. Such information is necessary in calculating the radiating surface of heating plants, designing or specifying material for a building, and making a comparison with other building material.

Heat is transmitted from one region to another region of lower temperature by conduction, convection, and radiation. During these investigations the total amount of heat transmitted was measured and no attempt was made to measure conduction, convection, or radiation separately.

METHOD AND APPARATUS

Laboratory: The investigations were carried on under actual conditions in a large laboratory of the Mechanical Engineering building.

Test Box: The method employed was that of using a double test-box arrangement, having the open side of each box in the same plane. See Figures 1, 2, 3, and 4. Inside dimensions of the outer box were 2 feet 4.5 inches by 2 feet 4.5 inches by 1 foot 8.25 inches, and of the inner box 1 foot by 1 foot by 1 foot. The walls of the boxes were built up of three layers of $\frac{1}{4}$-inch asbestos mill-board, a $\frac{3}{4}$-inch air space and $\frac{3}{4}$-inch wooden frame. The corners were well sealed with strips of wallboard tape. The face of the inner box was made of $\frac{1}{8}$-inch by 2-inch strap iron brought to a knife edge, one foot square. Adjustable supports were provided for the inner box to maintain perfect alignment of the bearing surfaces or open faces of the two boxes.

An adjustable clamping frame carrying twenty-eight $\frac{1}{2}$-inch by 6-inch adjusting bolts was supported at the corners of the box by $\frac{1}{2}$-inch threaded rods. The whole frame could be easily removed by loosening the four nuts at the corners. A sub-frame was used for each box to distribute the pressure equally over the bearing surface.

Test Specimens: Test specimens were cut 2 feet 9 inches square. They rested on the knife edge of the inner box and asbestos pad of the outer box. Pressure applied on the specimen by the clamping frame sealed the boxes air-tight. One-fourth-inch holes were bored in the specimen, through which the thermometers were inserted.

ELECTRICAL APPARATUS: The heating element for the inner box was 14 feet of Westinghouse heater coil wire, evenly distributed across the box at a distance of 2.5 inches from the bottom as shown in Figs. 2 and 3. The lead wires were taken through an insulator tube and packed with powdered asbestos. The heating element of the outer box was one complete Westinghouse heater coil, 500 W., 110 V., placed 2.5 inches from the bottom of the box.

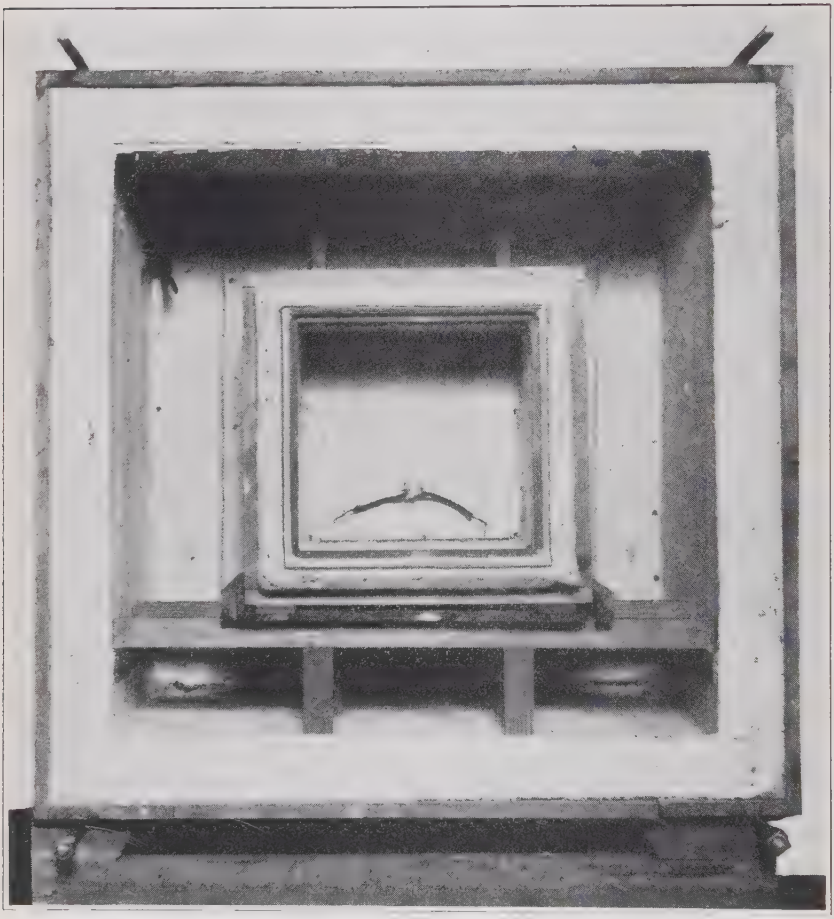


FIGURE 3.—Distribution and location of heating elements.

A Westinghouse portable, single phase wattmeter, 100 to 200 V., 2.5 to 5 A., 250 to 500 W., from the standardization laboratory of the University of Colorado, was used to measure the electric current supplied to the heating element of the inner box.

A 110 V., 7.55 A., 830 W. rheostat was used to control the temperature of the outer box. A 50 ohm, 3 to 1.5 A., 125 V. rheostat was used to vary the temperature of the inner box.

The source of electric current was the 110 V. alternating current power line of the College.

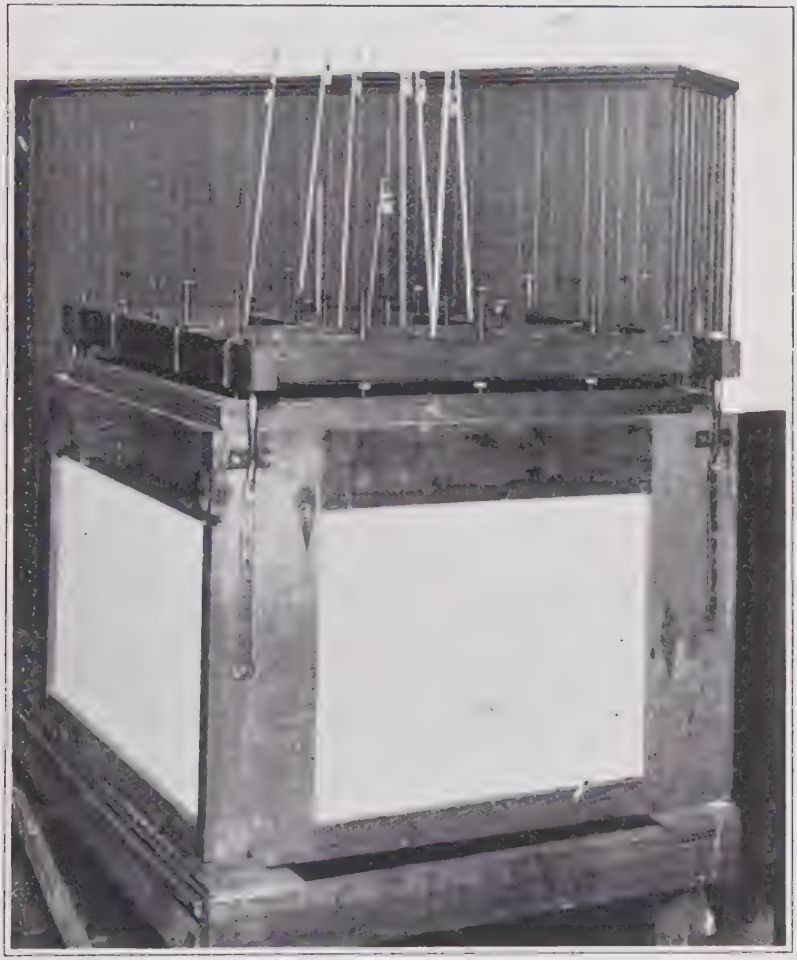


FIGURE 4.—Test box in operation.

THERMOMETERS: Twenty-four-inch engraved stem chemical thermometers with a range of 0 to 100 degrees Centigrade, graduated to one-tenth of one degree and capable of being read to one-twentieth of one degree, were used for all temperatures affecting the results of the investigations. Engraved stem chemical thermometers with a range of 0 to 300 degrees Fahrenheit, graduated to two degrees, and capable of

being read to one-half of one degree, were used for various temperatures not directly affecting the results of the investigations. The thermometers were not checked against any standard instrument, since the difference in temperature was desired rather than actual temperatures. The thermometers were checked against each other by holding all of them at certain temperatures and recording the readings.

BAROMETER: Barometer readings were taken during every test with a standard mercurial barometer.

METHODS OF CONDUCTING THE TESTS

Tests were made on each specimen at intervals of 10 degrees for a range of 25 to 75 degrees Fahrenheit difference in temperature of outside and inside air. No readings were taken until the temperatures indicated a constant flow of heat. Temperatures were taken at sufficient number of points to give an average temperature, as shown in Fig. 2.

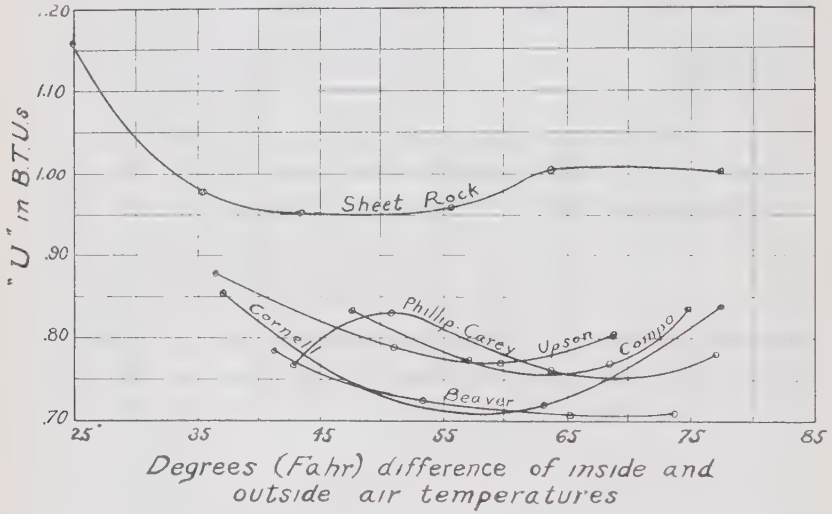


FIGURE 5.—Heat transmission (U) curves.

The test box was placed in an upright position during the tests, to permit an even flow of heat upward from the heating elements to the test specimen. See Figs. 2 and 4. Holding the temperatures in the two boxes the same would prevent any transmission of heat through the walls of the inner box or conduction along the test specimen. Then, theoretically, all the heat given off by the inner heating element must pass directly through the test specimen. However, in actual practice, even by experimentally locating the heating elements and controlling the heat input, it was found impossible to keep the temperatures of the two boxes exactly the same. But due to the insulating quality of the walls of the box, practically no heat was transmitted through the walls with a slight difference of temperatures. To bring the results within a greater degree of accuracy the approximate rate of heat transmission of the walls of the inner box was measured and the correction applied.

The test box was designed with a 6-inch fan driven by a motor on the outside, to circulate the air in the outer box. The circulation was incomplete and variations in the temperatures were produced. Eliminating the fan, properly arranging the heating elements, and setting the test box in an upright position, gave a natural, even flow of heat upward to the specimen.

The test specimen covering only one side of the test box and resting on the knife edge eliminated any question as to the heat transmitting area to be considered. There was no influence of air currents upon the surface resistance of the test specimen, since fans were not used to circulate the air.

Temperatures of the outside air were taken at different distances from the test specimen to get a temperature gradient showing the point at which the outside temperature became constant. Since the temperatures were taken directly above the specimen, the gradient could not be applied to actual conditions and will not be considered of much importance in connection with these investigations.

CALCULATION OF RESULTS

SYMBOLS:

W = Watts supplied to the heating element.
t = Inside air temperature.
T = Outside air temperature or room temperature.
A = Heat transmitting area in square feet.
H = Time in hours.
U = Total heat transmission, B. T. Us. per hour, per square foot, per degree Fahr. difference in temperature, per actual thickness.
3.412 = Factor to convert watts into B. T. Us. per hour.

FORMULA:

$$U = \frac{3.412\ W}{A\ (t-T)\ H}$$

FINAL RESULTS

	(t — T)	U	
Sheet Rock wallboard	24.98	1.1558	
	35.37	.9786	
	43.69	.9511	
	55.48	.9575	
	63.76	1.0055	
	77.36	1.0034	Ave. U=1.01
Beaver-board	41.21	.7864	
	53.40	.7238	
	65.11	.7074	
	73.78	.7093	Ave. U= .73
Compo-board	47.66	.8308	
	57.11	.7711	
	68.52	.7683	
	74.82	.8342	Ave. U= .80

Phillip Carey wallboard	42.85	.7678	
	50.79	.8305	
	63.78	.7614	
	77.15	.7800	Ave. U= .78
Cornell wallboard	36.91	.8536	
	47.04	.7471	
	63.19	.7185	
	77.37	.8391	Ave. U= .79
Upson wallboard	56.58	.8774	
	51.30	.7909	
	59.68	.7693	
	68.61	.8050	Ave. U= .81

DISCUSSIONS AND CONCLUSIONS

The results of these investigations deal only with heat insulating qualities of the wallboards and, as previously mentioned, have not been obtained from a purely scientific point of view. Corrections have been applied to bring the results within some degree of accuracy, but certain minor variations were immeasurable. However, the results are considered sufficiently accurate to be used for any practical purpose and should represent a fair comparison of the heat-insulating qualities of the various kinds of wallboard investigated.

The tests were not of long enough duration to indicate any effect of barometric pressure upon the rate of heat transmission.

INFORMATION OF GENERAL INTEREST ABOUT WALLBOARD

1. As an insulator of heat, it is a little inferior to common lath and plaster one-half inch thick.
2. It is quickly and easily applied.
3. It has a great number of uses other than wall construction.
4. It is superior to wood in many cases of light construction, for it is light, uniform, and leaves no cracks.
5. Contraction and expansion are not noticed under ordinary conditions.
6. In places of high temperatures or extreme temperature-changes the edges are liable to warp or come loose unless well stripped.
7. When exposed to moisture for any length of time it tends to soften and expand.
8. Types of wallboard such as Sheet Rock are fire-proof.
9. It lends itself very well to painting and tinting.
10. It is not as durable as lath and plaster.
11. It is in general more expensive than other kinds of material used for similar purposes.

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The Colorado Experiment Station

AGRICULTURAL DIVISION

HEAD LETTUCE IN COLORADO

By R. A. McGINTY



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FORT COLLINS, COLORADO
1923

The Colorado Agricultural College

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HEAD LETTUCE IN COLORADO

By R. A. McGINTY

Five years ago head lettuce as a commercial crop was practically unknown in Colorado. Here and there a gardener would occasionally grow a small patch for market and a few amateurs grew it for home use. In 1918, Mr. G. D. Isabel of Canon City, an experienced truck grower, leased ten acres of land near Buena Vista and planted it to head lettuce. The crop was a wonderful success, yielding, it is said, a return of $7,000. The following year a larger acreage was planted and another good crop harvested.

Exaggerated stories of the large profits made in growing the crop were spread broadcast and almost every high-altitude section in the State began to "get into the game." The poor clerk, out of a job, the coal miner, off on a strike, and the capitalist with his thousands to invest, all became interested in a crop promising such great returns. Not only from Colorado, but from many other states came numerous inquiries for information as to the possibilities offered. In 1922, something like 6000 acres were planted to lettuce in the State, and in spite of the rather disastrous results of the season, indications point toward a still larger acreage in the future.

The concensus of opinion is that head lettuce has come to stay and that it will be one of the State's most important vegetable crops; in fact it already outranks, as far as acreage is concerned, all vegetables except potatoes and dry beans. While some growers have become discouraged and say they will not plant again, others consider it a good crop even under adverse conditions and expect to stick to it.

As indicated above, a great many people have been attracted to the lettuce sections by visions of prosperity and many of these have had very little agricultural experience, much less experience with crops as exacting as head lettuce. The need of this class of growers for information, together with a general lack of knowledge regarding the culture of the crop under the new conditions has made it seem desirable to publish this bulletin giving all the available information on the subject.

THE OUTLOOK FOR LETTUCE GROWING

The questions are often asked: Will the growing of head lettuce be overdone in Colorado? Will it be possible with the increased production to market the output successfully? Time alone can answer these questions. The land adapted to lettuce

growing is limited as regards climatic conditions, accessibility or facilities for irrigation; and expansion cannot continue indefinitely. The quality of the Colorado product is not excelled by that from any other section, which insures a good demand. The injunction to "eat vegetables for vitamines" is obeyed with greater alacrity than ever before, thanks to doctors and dieticians, and good head lettuce is an easy medicine to take. Of course there will be years when poor distribution or possibly over-production of a poor grade of lettuce will result in comparatively low prices, but growers on the whole seem to be



Lettuce field of S. J. Burleson, Buena Vista, July 4, 1922. The first head lettuce of any consequence in Colorado was grown on Mr. Burleson's land.

optimistic. Some state that they consider lettuce the best crop they can grow, even in the face of the poor returns of last year. However, one of the largest shippers of lettuce in 1922 expects, in view of the probable increased acreage, that the grower will receive less money for the 1923 crop.

While a gradual increase in the acreage of head lettuce in Colorado is to be expected and encouraged, it would probably be better for all concerned if the acreage for the time being could be somewhat reduced. There is no question but that growers have undertaken to handle too large areas in the majority of cases. The crop is one that demands special attention and no one should plant more than can be properly and promptly cared for at all stages of growth. This applies especially to those who are inexperienced in handling garden crops such as lettuce. Quality rather than quantity should be the aim.

One factor which promises to be of much importance in the

development of the lettuce-growing districts is the introduction of other crops such as peas, cauliflower, cabbage, and possibly celery. It has already been demonstrated that peas and cauliflower can be grown successfully in the mountain districts. When properly handled they may be as valuable as lettuce itself and the diversification made possible by their use will be a great advantage.

Marketing problems, lack of knowledge as to cultural requirements, diseases, etc., provide uncertainties which, many times, are not fully appreciated. These problems, however, do not seem to be beyond solution and in time will doubtless be worked out. This, together with the proper organization and cooperation of growers who should strive toward the production of quality lettuce and other vegetables will eventually establish the industry upon a stable and profitable basis. As a writer from the Imperial Valley, in California, puts it, "lettuce growing will have to be considered a regular line of farming and not a speculation. A rancher will not figure what years he can 'make a killing,' nor which crop of lettuce will 'make a killing' for him; he will have a definite amount of lettuce every year, produced evenly during the lettuce season. He will expect to sell some of that lettuce for little or nothing, perhaps, but he will feel certain that for a good part of that season prices will be high enough to make a comfortable profit for him."



Heads of mountain lettuce are as crisp and firm as cabbage—Experimental Plots, Colorado Agricultural Experiment Station, Buena Vista.

EXPERIMENTS WITH HEAD LETTUCE

The numerous appeals for information as to the details of lettuce culture led the Horticultural Department of the Agricultural Experiment Station to begin some experimental work at Buena Vista in 1922. The objects of the experiments are to determine the best cultural practices, to develop, if possible, a better strain of lettuce for Colorado conditions, and to investigate methods for avoiding losses due to diseases and "shooting to seed." The work will be continued until light has been thrown upon these problems.

The author of this bulletin will be glad to answer questions or receive suggestions regarding any phase of lettuce growing. The industry is new and it is only by the exchange of ideas and experiences that it can be put on a permanent and stable basis in the shortest time. Communications should be addressed to the Horticultural Department, Colorado Agricultural College, Fort Collins, Colorado.

CARLOT SHIPMENTS OF HEAD LETTUCE FROM POINTS IN COLORADO, 1922

Station	Altitude	June	July	August	Sept.	Oct.	Total
Alamosa	7546		1	6	—	—	7
Antonito	7888		—	1	—	—	1
Aspen	7900		—	1	3	1	5
Avon	7455		10	37	22	4	73
Buena Vista	7958		10	60	71	12	153
Blanca	7562		—	—	2	1	3
Carbondale	6142		—	8	3	—	11
Canon City	5344	1	—	—	1	6	8
Cotopaxi	6385		—	1	4	3	8
Creede	8840		—	40	23	—	63
Del Norte	7876		—	15	7	—	22
Denver	5280	4	3	3	—	—	10
Divide	9198		—	7	25	—	32
Eagle	6598		3	10	13	—	26
Florence	5199		—	10	59	16	85
Glenwood Springs	5793		—	2	5	1	8
Granby	7935		—	1	21	—	22
Granite	8981		1	10	4	—	15
Leadville	10140		—	—	4	—	4
Minturn	7825		—	28	5	—	33
Monte Vista	7660		1	—	—	—	1
Pando	9209		—	1	3	—	4
Pueblo	4690	3	1	11	21	8	44
Salida	7050	—	4	16	15	3	38
Steamboat Springs	6680		—	2	—	—	2
Tabernash	8310		—	1	7	—	8
Toponas	8252		—	—	12	1	13
Westcliffe	7861		—	25	36	14	75
Yampa	7884		—	15	37	1	53
Total		8	34	311	403	71	827

WHERE LETTUCE GROWS BEST

Head lettuce in Colorado is a high-altitude crop. Experience has shown that elevations of from 7000 to 9000, or even 10,000 feet, produce the best lettuce. At these elevations the days are not often extremely warm and nights are uniformly cool, conditions that make for crisp, hard heads with a minimum of tip-burn and seed stalks. In certain seasons successful crops may be grown at altitudes of 5000 to 7000 feet, but the chances for a good return are much less than at the higher elevations.

Below is given a table showing the points from which head lettuce was shipped in 1922. The altitudes of the shipping points are given together with the monthly, carlot shipments in each case. Absolutely accurate figures as to shipments are very difficult to obtain. Those given in the table include not only the straight carloads of lettuce, but also many cars of mixed vegetables, of which lettuce made up the greatest portion.

A great deal of lettuce is shipped by express in small lots for which no data is obtainable. It is said that the Denver postoffice handled as much as 18 carloads of head lettuce by parcel post in 1922.

From the table it will be seen that the Buena Vista district, which is the oldest lettuce-growing locality in the State, still leads in production. Other districts are advancing rapidly, however, and a few years may see them take the lead. In some cases the altitude of the shipping point is much lower than that of the territory where the lettuce is actually grown. This is true of Pueblo, Florence and Eagle, which are from 500 to 1000 or more feet lower than the ranches which grow lettuce shipped from these stations.

The transportation factor is an important consideration in the development of the lettuce industry in any locality. A glance at the figures reveals that the most important shipping points are located on standard-gauge railroads where transportation and handling charges are less than elsewhere. Many localities in the State, where there are ideal climatic and soil conditions for the growing of the crop, are handicapped by lack of adequate transportation facilities and must grow lettuce in only a limited way, if at all.

Shipments from Salida include lettuce grown at Gunnison and Sargent. The lettuce grown at these points was loaded in field crates and shipped in box cars to Salida where it was packed for final shipment.

INFLUENCE OF SEASON ON LETTUCE GROWING

Head lettuce requires about ninety days from seeding to maturity. In some of the localities, at the higher elevations,

seeding cannot be done until the middle of June, while hard freezes may damage the crop late in September, if it is still in the field. This leaves no time to spare and the grower must be prepared to plant, cultivate, and harvest without delay when the time comes for these operations, or his crop will be a failure.

In the Canon City, Pueblo, and Denver districts, and in other localities with similar conditions, it is possible to grow two crops of lettuce on the same ground in one season. The early crop matures in June and the late crop in October or November. In the majority of the lettuce-growing localities the season is long enough to allow plantings to be made from May to July first with the harvesting of the crop extending over a corresponding period, but not sufficiently long to grow two crops.

The statement is often made that lettuce maturing late in the season, when the weather is cool, is more likely to be a success than the earlier crop. While this is perhaps true as a general proposition, it is of interest to note that in some years the earlier plantings have given the best results. With a comparatively cool summer during which seasonable rains occur, the early crop may head well. The prices for early lettuce are sometimes better than for the late crop, though often the reverse is true.

COMPETITION FROM OTHER SECTIONS

The states of California, Idaho and Washington all ship considerable lettuce of the "Western Iceberg" type during the months of June, July, August, September, and October, while other western states ship a much smaller quantity, the latter amounting in the aggregate to about one hundred cars in 1922. In the production of this type of lettuce, Colorado possesses advantages of location and transportation not shared by other sections producing the same kind of lettuce and should have no trouble competing with them.

New York ships heavily during this period and a considerable quantity moves from Michigan, Minnesota and New Jersey at the same time. The lettuce grown in these states is, however, of the "Big Boston" type and cannot compare as to quality with the Colorado product. It does, however, tend to depress the market in eastern centers as it sells at a much lower price than "Western Iceberg."

Colorado lettuce is favorably known in the large markets of the country and when of the best grade its quality is unsurpassed. Other states, particularly Idaho and California, also have a reputation for high-grade lettuce and in order to meet

competition from these sections successfully, Colorado growers should use every effort to produce a first-grade product. There is rarely a time that No. 1 lettuce will not bring a good price while the third-grade product is sometimes not salable at any figure. Poor-quality lettuce will, of course, due to various conditions, some of which are unavoidable, continue to be grown, but the amount of it should be reduced to the lowest point possible.

The following table shows the number of cars shipped during the Colorado lettuce season by the most important competing states in 1922.

CARLOT SHIPMENTS OF HEAD LETTUCE FROM MOST IMPORTANT COMPETING STATES, 1922

States	June	July	August	Sept.	Oct.
Western Iceberg					
California	390	184	100	91	221
Idaho	37	1	35	9	558
Washington	133	240	269	108	61
COLORADO	8	34	31	403	71
Big Boston					
Michigan	11	59	11		
Minnesota		13	38	26	8
New Jersey	42	3		1	151
New York	163	982	1006	667	351

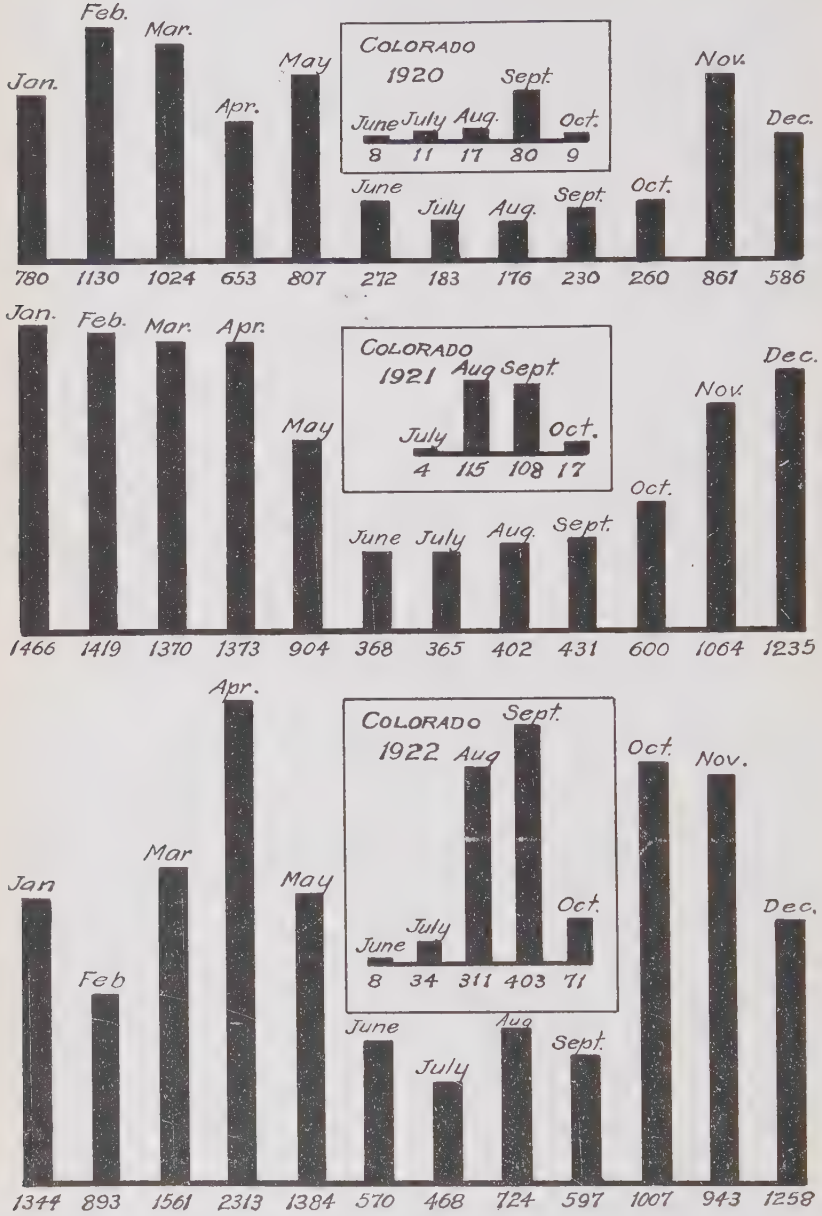
In this connection the distribution of the lettuce crop of the United States is of some interest. On the following pages the distribution of the crop for the entire United States, for the states producing "Western Iceberg," and for Colorado is illustrated graphically. These show that during the months of July, August, and September, when the bulk of the Colorado crop goes to market, the supply of lettuce is less than at other periods. This is probably a fortunate condition because, with the supply from home gardens and with an abundance of other green vegetables, there is not likely to be as great a demand for head lettuce as prevails during the late fall, winter and spring.

In the table below are shown the prevailing wholesale prices for "Western Iceberg" lettuce in some of the principal markets of the country. The prices shown are the averages of

WHOLESALE PRICES OF NO. 1 "WESTERN ICEBERG" LETTUCE AVERAGE FOR YEARS 1919, 1920, 1921 AND 1922

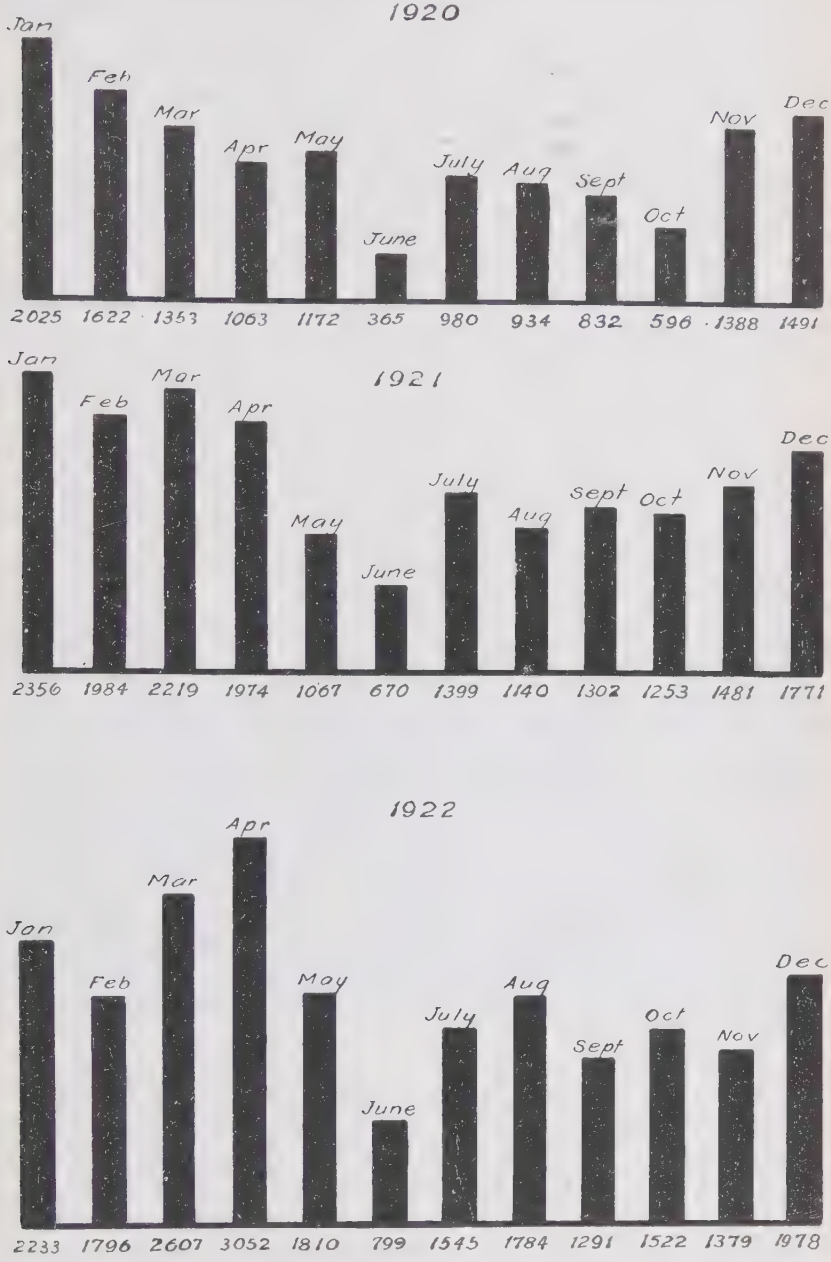
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Chicago	5.15	5.05	5.50	5.60	4.25	..	4.85	4.30	3.25	..	3.50	3.85
Cincinnati	4.25	3.95	4.25	4.70	3.80	4.00	3.65	3.20	3.25	3.25	3.50	4.25
Kansas City	4.00	4.50	4.45	4.95	4.20	3.50	5.00	5.05	4.50	4.85	4.70	4.35
Dallas	4.35	4.75	5.00	5.50	4.60	4.25	4.50	4.50	5.10	5.50	5.10	5.10
Pittsburg	4.50	5.30	4.30	4.75	5.85	3.85	2.95	1.85	2.35	4.00	4.75	5.00

DISTRIBUTION OF WESTERN ICEBERG LETTUCE.
MONTHLY CARLOT SHIPMENTS
1920, 1921 AND 1922



In the above charts are included figures for the states of Arizona, California, Colorado, Idaho, Oregon, Utah, Washington and Wyoming. The small charts for Colorado are drawn on a larger scale than the main charts. Note the advantageous position of the Colorado crop.

DISTRIBUTION OF HEAD LETTUCE—UNITED STATES.
MONTHLY CARLOT SHIPMENTS,
1920, 1921 and 1922.



In the above charts are included figures for both Western Iceberg and Big Boston letture. Note the relatively low supplies during Colorado season.

the prices which have prevailed during the past four years. The figures are not entirely complete but are the most accurate available.

Dallas and Kansas City seem to pay somewhat better prices during the Colorado season (June, July, August, September, October) than the other points. Their location is such that prices are not affected much by the heavy output of New York during these months, while the other markets, Pittsburg especially, are considerably influenced. On the whole, prices seem to fluctuate less from month to month than might be expected.

No prices are obtainable for No. 2 and No. 3 grades. The high percentage of these grades in Colorado last year was largely responsible for the low prices obtained, and it is doubtful whether it ever will be profitable to ship the No. 3 grade.

CULTURE OF HEAD LETTUCE

Soil and its Preparation.—Head lettuce is grown upon a variety of soils, but a dark, rich, loamy soil containing considerable leaf mold such as is found in areas from which aspens have been removed is usually preferred. Such soils always contain a good deal of sand and while one containing an excessive proportion of sand is usually to be avoided, such a soil may grow first-class lettuce. Light-colored soils do not, as a rule, give as good results as the darker ones, since they are apt to be poorer in plant food and the lettuce grown on them more subject to tip burn. Land with some slope is preferable to the level areas on the valley floor. This is especially true where there is danger of early freezes in the fall which will damage the crop on the low lands while more elevated and sloping grounds are likely to escape injury. However, the valleys often produce good lettuce.

The land should usually be plowed in the fall so that freezing and thawing during the winter will leave it in a good, mellow condition and so that manure applied before plowing, or other vegetable matter which is plowed under, will have a chance to become incorporated with the soil. If the soil cannot be fall plowed, then the plowing should be done as early in the spring as the ground can be worked.

In the work of preparing the land for lettuce, the grower should keep constantly in mind that he is dealing with a garden crop and therefore the soil should be put into the best possible shape. The surface should be left as fine as harrowing and dragging will make it, and should be leveled as well as possible. A survey of the lettuce fields shows very clearly that not enough attention has been given to these details in the past. A poor seedbed means poor germination of seed with the resulting poor stand of plants, and difficulty in cultivating the crop while the

plants are small, while land which is not level makes irrigation difficult and unsatisfactory.

Fertilizers.—The use of fertilizers in growing lettuce has not engaged the attention of any large percent of growers up to this time, but a few have tried them in a small way, and others are beginning to wonder if the use of some kind of fertilizing material would not be advisable.

In practically all cases beneficial results have been reported where manure was used. In experiments conducted last year at Buena Vista, the Department of Horticulture found that manure at the rate of twenty tons per acre caused the crop to mature considerably earlier and to head better than in the case where no manure was used. It was also found that nitrate of soda and sulfate of ammonia, both of which supply nitrogen, produced much the same effect when used at the rate of 200 pounds per acre. The results of one season are, of course, not conclusive and the experiments will be repeated.



A field of good lettuce nearing maturity.

The soils in the lettuce districts, especially those which have been cultivated for a few years, are apt to be lacking in both humus and nitrogen, so that the use of fertilizers, where obtainable, seems advisable. Manures supply not only plant-food materials but improve the physical condition of the soil, making it more friable, and should be applied in the fall and plowed under before the ground freezes. If put on in the spring, it should be well rotted. One grower reports good results where four

ordinary wagon-loads per acre were used. Probably better results would follow somewhat heavier applications.

The use of chemical fertilizers such as nitrate of soda, while apparently beneficial, is not recommended until tried out over a longer period. In the event they are finally recommended at all, they probably should not be used exclusively, but to supplement stable manures or some green manure crop which has been plowed under.

A crop of alfalfa or some other legume turned under in the fall prior to planting is desirable and is advised where possible.

Acreage to Plant.—The amount of lettuce planted by individual growers varies from one to 150 acres. There is a well-defined opinion that the majority of growers plant too large an acreage which results in some of the crop being neglected at certain stages. One man can look after five or six or more acres, depending upon conditions, except at thinning and harvesting time when help will be needed. In Idaho where boys are employed to do the thinning, one boy will thin an acre in about six days. It should be remembered that lettuce is a crop requiring the methods of the garden rather than the hay field and that one acre properly cultivated and irrigated may give a better return than ten acres poorly handled.

Varieties.—There is only one variety of head lettuce grown in the mountain districts and the correct name of this variety is New York, although it is known under other names, such as New York Wonderful, Los Angeles Market, and Mountain Iceberg. It belongs to the so-called crisp-head group of lettuce varieties, is dark green in color and the most desirable strain produces round heads. There are other strains, one of which is conical headed (the original type) and not considered so desirable. The name Iceberg, often applied to this lettuce, is a misnomer, as the true Iceberg variety differs from New York in being much lighter in color and in forming heads which are not so firm as those of New York. One seedsman predicts that the Iceberg variety will be grown considerably for the early crop at the lower altitudes as it is more resistant to heat at the time of heading, which with early lettuce takes place in June or early July.

Experiment has shown that many other varieties of head lettuce can be grown in Colorado but New York is the type demanded by shipper and consumer and the kind which should be planted in the mountain districts. On the plains where it is desirable to grow head lettuce for home use, varieties like Mignonette, May King, or Big Boston, the latter the popular shipping variety in the East, are more likely to form reasonably good heads than the variety New York.

Seed.—One of the greatest difficulties of the Colorado lettuce grower has been the inability to obtain seed of good quality. It appears that seed of the New York variety has been scarce and this may have resulted in some seed getting into trade channels which should never have been sold. At any rate a great percent of off-type plants can be found in most of the lettuce fields. One of the largest and best lettuce-seed growers in California has the following to say regarding the production of seed of the New York:

"New York lettuce is the most difficult variety we have to grow. Owing to density, the heads have to be opened to allow the seed stalk to come through. The variety is a very shy seeder and yields less than one half the seed of other sorts. Great care has to be used in harvesting as the seed shatters easily and a strong wind sometimes wastes a large portion of the crop of seed. New York lettuce was originally a conical-shaped type. By constant selection and working from individual selections we have developed a flat- or rounded-head type, making a larger and heavier head. This strain is extremely hard to fix."

They state, in addition, that they hope to have the type thoroughly fixed in another year or two.



Ice house built cooperatively by growers at Buena Vista. Capacity about 10,000 tons. The ice is used both in the crates and in refrigerator cars.

Growers should insist upon the best seed available as cheap seed is not likely to be worth the space it occupies. Prices quoted at the present time vary from two to four dollars per pound. With only a pound or a pound and a half required to the acre, the cost of seed is a small matter, considering the possible value of the resulting crop. If any doubt exists as to the germination of seed, it should be tested at home or a sample sent to the Seed Laboratory, Colorado Agricultural College, Fort Collins, where it will be tested without charge.

The question sometimes comes up as to whether or not the seed of plants which have formed seed stalks due to unfavorable weather conditions is suitable for planting. It is possible that such seed may prove satisfactory, particularly if the strain is known to be a good one, but it is believed that the best and safest policy is to use no seed except from plants which have first formed marketable heads of the desired type.

Planting.—At elevations of 7000 to 9000 feet where the bulk of Colorado lettuce is produced, planting is done during May. June, and the early part of July. Fall planting has been tried and while in some cases it has been successful, on the whole it appears not to have been satisfactory. From some of the milder sections of the State, as the Canon City district, some good reports have been received regarding this method. In fall planting, the seed is sown in October, and the plants make some growth before hard freezes set in. Being very hardy, they winter over satisfactorily and begin to grow with the first warm weather in the spring. Sometimes the seed is planted in the fall but does not germinate until spring, when it is ready to grow as soon as conditions are favorable.

The majority of growers favor the distribution of the planting over a considerable period rather than doing it all at one time. For example, one-third or one-fourth of the crop may be planted at a time, with ten days or two weeks between the plantings. This enables the thinning and harvesting of the crop to be done more promptly and satisfactorily as these operations are in this way distributed over several weeks instead of coming all at one time.

Spring planting at the lower elevations should be done as early as the ground can be worked so that the lettuce will have a chance to mature before extremely warm weather sets in. The late crop may be seeded in July and will mature in October.

Some growers advocate the transplanting of lettuce for the early crop. Transplanting can be done about as easily as thinning, a proper stand is assured, and if properly handled, the plants should head earlier, thus having a chance to avoid the hot weather. When handled in this manner, seed is planted in a hotbed February 15 to March first and the plants are set in the fields about the middle of April. Before transplanting, the plants should be hardened by gradually exposing them to outside conditions by raising the sash of the hotbed.

The amount of seed to plant depends upon the quality of the seed and upon the condition of the soil at planting time. With good seed and the best of conditions for germination, one pound, or even three-fourths of a pound of seed per acre is considered

sufficient, while one and a half or two pounds may be required under more adverse conditions.

Seed is sown, as a rule, with some type of seed drill, those of the Planet Jr., Iron Age, and Iron King type being most used. These may be operated by hand, or they may be rigged up so that a horse or small garden tractor can pull two, three, or four of them, thus planting two to four rows at a time. Instances are known where beet planters have been used, the seed being mixed with sand, one pound of seed to thirty pounds of sand, to facilitate even planting.

Planting Distances.—A questionnaire sent to growers shows that the majority prefer distances of from twenty to twenty-four inches between rows and from twelve to fourteen inches between plants in the row. Some, however, specify a distance of twenty-six to thirty-two inches between rows. The greater distance between rows allows the use of one-horse cultivators to better advantage than where rows are closer together. Planting is sometimes done in double rows, furrows being laid out from thirty to forty inches apart and a row planted on each side of the furrow. The rows of each pair are about twelve or fifteen inches apart and the space between the pairs of rows about eighteen to twenty inches wide. The latter space is cultivated throughout the season. The narrower space is used for irrigating and is cultivated after each irrigation the first of the season, but later, when the plants begin to occupy the space, is left alone.

Seed should be covered one-half to one inch deep depending upon the season, soil and moisture conditions. The depth of planting should be shallow if done early in the season when the soil is cold and damp, and deeper if done later when it is warm and dry. In light sandy soils the seed may be put deeper than in heavier types.

Cultivation.—Observations indicate that lettuce requires more cultivation than is usually given it in Colorado. Growers differ as to the number of cultivations which should be given, some believing that two or three are sufficient while others recommend "one cultivation a week," or "frequent cultivations" or "cultivation after each irrigation." Still others think that from four to six cultivations will produce a successful crop. The Idaho Experiment Station recommends a cultivation once every week or ten days. Lettuce responds to frequent cultivation and it is hard to overdo it.

Where the soil has been properly prepared, cultivation need not be deep. What is needed is to stir the surface soil so as to kill weeds and form a dust mulch. In many cases this work is done with a hand cultivator, or wheel hoe which stirs the soil

to a depth of about two inches. In other cases horse-drawn cultivators are used.

Cultivation after irrigation and after rains is especially important as it prevents the soil from baking and conserves the moisture. The leaves of lettuce are very brittle early in the morning and on cool, cloudy days. When the plants have reached good size, it is probably better to delay cultivation until the day is somewhat advanced as the leaves, due to the warmth and lessened turgidity, will not be so likely to be broken off when brushed by the cultivator.

Tools.—Some growers are using beet tools in handling lettuce with very good results and it is believed that they are worth a trial by others since they offer the possibility of doing the same amount of work in less time. To use such tools successfully the ground must be in reasonably good condition and rows must be straight and a uniform distance apart. Besides facilitating cultivation, level ground and straight rows will also make irrigation and other operations less difficult.

Hand seeders and hand cultivators have been popular so far in the lettuce fields, but there seems to be a stronger sentiment developing in favor of horse-drawn tools. For small areas, where land is valuable and intensive culture desirable, the hand tools are very satisfactory but for larger operations, the work is more easily done with horse power. One-horse cultivators of the seven-, nine- and twelve-tooth types are well adapted for use in the lettuce fields. There are also one-horse cultivators, adapted to lettuce culture, on the market, which cultivate two rows at a time.

The newer models of light garden tractors seem to be fairly well adapted to this class of work. They have been tried to a limited extent and while their value has not been entirely proved they show some promise. Some makes are provided with seeding attachments which will plant two or three rows at one time. These machines can also be used for other work around the ranch, such as pumping, grinding, etc.

Thinning.—This is one of the most important as well as one of the most laborious operations connected with lettuce growing. It is a case where the cultivator must literally assume a prayerful attitude and get down on his knees to do the work properly. The small plants stand close together in the row and to avoid injury to the ones left, the others must be carefully removed. Only one plant should be left in a place and the work should be done when the plants have developed only three or four leaves, or before they tend to become spindling. A plant every twelve or fourteen inches is close enough on good soils. Hoes, knives and tablespoons are used in thinning.

Irrigation.—There is a great deal of difference of opinion as to how lettuce should be irrigated. The majority, however, is inclined toward the view that frequent, light irrigations are best. Thorough soakings when the plants are small may do no harm, but only light irrigations, frequent enough to keep the soil always moist, are advisable as the crop nears maturity. Water can often be run in every other middle at one irrigation and in alternate middles the next time. Night irrigation is practised by many growers, especially during hot weather and when there is danger from freezing.

It seems hardly necessary to say that water should always be applied in furrows but cases are known where the flooding method has been used either through ignorance or because the land was not sufficiently well leveled to avoid it. Where this method is followed the plants are frequently covered with mud and when the ground dries out after irrigating, the surface is left in bad shape due to baking.

Crops of good lettuce have in some instances been grown under dry-farming conditions in localities where the rainfall is above the average for Colorado, but the extreme uncertainty of producing a profitable crop under such conditions should cause prospective growers to select sites where there is plenty of water for irrigation.

Shooting to Seed.—At times lettuce growers experience great losses from the plants shooting seed stalks before forming good marketable heads. This trouble has been ascribed to unusually warm weather which sometimes prevails during the maturity of the crop and which no doubt does influence it to a great extent. Other factors, however, such as a poor strain of seed, improper irrigation or lack of cultivation probably have a good deal to do with the trouble.

When a lettuce plant forms a head the next step, normally, is to produce a seed stalk. The head may stand for several days, under ideal conditions, without shooting to seed, but in hot weather, the seed stalk may begin to form before the plant has made a firm head. In many cases the trouble is not evident until the head is examined, when it may be found that the seed stalk has already grown considerably and is curled up inside the head. Such heads are usually characterized by a bitter taste and should never be packed for market.

Cultural methods which avoid any check in the growth of the lettuce and the planting of as good a strain of seed as can be obtained should aid in reducing losses from shooting to seed.

Diseases and Insects.—Tip burn is the most serious disease



Field of lettuce after "shooting to seed," one of the worst troubles the grower must contend with.

of lettuce in Colorado, some loss due to it being reported every year.

The January, 1922, bulletin of the California Department of Agriculture contains the following discussion of this disease:

"Severe losses are sometimes occasioned by tip burn, which is characterized by the blackening of the edges of the inner leaves and which, under favorable conditions, will result in a partial or total decay of the interior of the head. It is, however, often impossible to detect any external symptoms of this condition. The disease is of a non-parasitic nature and the damage is usually done after the plants have started to head. It is most prevalent when bright, hot weather follows a period of cloudy or rainy weather. Considerable variation of infestation is found in the different classes of soil. Lettuce growing in soils of high

water-holding capacity shows less injury than that grown in soil with an insuffiicient supply of moisture. In the Imperial Valley this disease seems to be closely related to alkali conditions. Slimy soft rot will often start in the weak tissues caused by tip burn, while the lettuce is being shipped or held in storage, causing total loss of that head. Heads which are only slightly diseased will invariably develop a bitter flavor."

Lettuce affected with tip burn should of course not be shipped as the bitter taste is disagreeable to consumers and the heads are quite apt to go to pieces in transit.

Good seed and good culture are the best remedies known for this disease. Frequent, light irrigations are recommended by some during hot, dry spells. It may be possible to develop a strain of lettuce which will be resistant to tip burn and experimental work with this object in view is already in progress.

The disease known as "slime" is apparently caused by decay organisms gaining entrance to the head through other injuries such as tip burn, or bruises caused from feeling of the head to determine whether it is firm or not. Insect injuries may possibly furnish a means of entrance for the germs of decay. This trouble produces a slimy rot which in a short time makes the head totally worthless. It may cause the deterioration of lettuce after it has been started on its way to market and is one reason why heads showing signs of tip burn, or known to be affected with it, should not be shipped.

Another disease sometimes known as "rust" seems to be a form of tip burn.

The only insects which have been reported as damaging lettuce are cutworms and wireworms. These pests sometimes occur in sufficient numbers to do real harm to the crop. The identity of the harmful species of both cutworms and wireworms is somewhat in doubt and since the different species require different treatment it seems best to omit specific directions for combating them. It is at best difficult, if not impracticable, to control them. Growers having trouble with these or other insect pests should send specimens of them to the Department of Entomology, Colorado Agricultural College, Fort Collins, together with all information possible regarding their numbers, the length of the period during which they are observed damaging the plants, previous crops grown on the land, and any other data which may have any connection with them.

Certain species of cutworms and wireworms have been effectively destroyed by the use of poison-bran mash which is

prepared according to the following formula found in Colorado Experiment Station Bulletin 210, Insects and Insecticides:

Paris green	3 pounds
Bran	50 pounds
Syrup (cheap)	4 quarts
Water	5 gallons
Lemons	10

Mix the Paris green and bran together while dry; dissolve the syrup in the water; squeeze the lemons into this and finely chop the peel and pulp and add them also; pour this mixture into the bran and Paris green, and stir so as to dampen the mash thoroughly. The lemons may be prepared by putting them through a meat grinder. Distribute the mixture broadcast in as fine particles as possible where the worms are most abundant. The application should be made towards the evening or early (between 4 and 7 o'clock) in the morning. From 3 to 5 pounds of dry bran is usually sufficient for an acre of land. Never distribute in little piles.

Harvesting, Grading and Packing.—These operations deserve much attention and care since the final results of the season's work may, in a large measure, depend upon them.

Harvesting should be done in the morning when the heads are cool and crisp, but, according to California authorities, the heads should not be cut while wet or when frozen as they are then much more susceptible to subsequent heat or rot.

It is necessary to go over the field about three times in harvesting the crop, so that the lettuce may be cut as soon as it is ready. Prompt cutting of matured heads is important during warm weather, but after the days become cool, cutting may be delayed somewhat if necessary.

The plants are cut just below the head in such a way that all the leaves are left intact. One who is experienced in harvesting lettuce can tell at a glance what heads are ready to cut. The heads are put into field crates as soon as cut with the bottom of the head up, and should be taken to the packing shed at once. Everything possible should be done to keep the heads cool and prevent wilting by sun and wind. Putting crates in the shade as soon as filled or covering with canvas will be of advantage in this particular.

At the packing shed the lettuce is trimmed, graded and packed into crates which are at once loaded into refrigerator cars. The standard crate used in Colorado is what is known as the Los Angeles crate and measures 13x18x24½ inches. The crate is lined with paraffin paper and the heads packed two to



A lettuce-packing shed. Note the cull lettuce on platform at right of picture.

four or even five dozen to the crate, depending upon the size of the heads. Crushed ice is placed between the layers of heads in the crate, about 35 or 40 pounds being used for this purpose.

Many growers are beginning to recognize the need for strict grading of the lettuce shipped and urge that a high standard be set. In 1922 the Standard U. S. grades were in force in Colorado, all cars being duly inspected before shipment. The following specifications for head-lettuce grades are taken from a booklet entitled "Standardization of Colorado Fruits and Vegetables," published by the Colorado Division of Marketing, July 1, 1922:

U. S. GRADES FOR HEAD LETTUCE

U. S. Fancy No. 1

U. S. Fancy No. 1 shall consist of heads of lettuce of similar varietal characteristics which are fresh, well trimmed, and firm; which are not wilted, decayed, or burst, and which are free from seed stems and doubles and damage caused by freezing, tip burn, disease, insects, or mechanical or other means.

Each head of lettuce shall weigh not less than one pound.

U. S. No. 1

U. S. No. 1 shall consist of heads of lettuce of similar varietal characteristics which are fresh, well trimmed and fairly firm; which are not wilted, decayed or burst, and which are free from seed stems and doubles and from damage caused by freezing, tip burn, disease, insects or mechanical or other means.

Each head of lettuce shall weigh not less than ¾ of a pound.

U. S. No. 2

U. S. No. 2 shall consist of heads of lettuce of similar varietal characteristics which are fresh, well trimmed, and which are free from seed stems and from damage caused by freezing injury, tip burn, disease, insects or mechanical or other means.

Each head of lettuce shall be of merchantable size.

In order to allow for variations incident to proper grading and handling, not more than 10 percent by count, of any lot of the above grades may be below the requirements of the grade, but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 3

U. S. No. 3 shall consist of heads of lettuce which do not meet the requirements of any of the foregoing grades.

Definition of Terms

"Similar varietal characteristics" means that the heads in any container have the same color and characteristic leaf growth. For example, lettuce of the Iceberg and Big Boston types must not be mixed.

"Fresh" means crisp and green.

"Well trimmed" means that the head is protected by green wrapper leaves, but excessive wrapper leaves and those which have been noticeably injured by decay, worms, tip burn or other means must have been removed.

"Firm" means that the head is compact and feels solid.

"Seed stems" means those heads which have seed stems showing or in which the formation of seed stems has plainly begun.

"Fairly firm" means that the head yields readily to pressure but is not soft or spongy.

There is no question but that the strict enforcement of grading standards will do as much as anything to put the Colorado lettuce industry on firm foundation. It is of interest, in this connection, to note that figures of the Division of Marketing covering 537 straight carloads of lettuce inspected in 1922 show that only forty percent graded U. S. No. 1 while sixty percent was under this grade. The statement is made that the percent of No. 1 lettuce would have been higher had it not been for the indiscriminate mixing of different grades in the crates. which lowered the grade of the whole lot. The lettuce of 1922 was of course of somewhat poorer quality than in other seasons, due to unfavorable weather conditions.

Marketing.—The handling of lettuce after it reaches the packing shed is usually done by some marketing agency. Such agencies may be organizations composed of growers or they may may be private concerns. They operate the packing sheds, furnish crates, and do the grading, packing, loading and marketing. They often contract to handle the grower's crop charging a certain price for the service. In 1922 one grower's organization charged $1.00 per packed crate for packing and marketing the lettuce. In addition to the above-mentioned services, some of the agencies handle seed and other supplies which are sold to the growers whose output they handle.



Car of lettuce showing method of loading. Chunks of ice are placed on top of each crate in upper layer

It is important that the grower make some arrangement in advance for the marketing of his crop. Cash buyers are sometimes glad to pick up a few cars at a good price, but cannot be depended upon to handle the entire crop, and this is especially true when the supply of lettuce is plentiful. The established organizations or agencies cannot be expected to take care of the grower at such times, when he has not favored them at other times. A reliable agency should be selected by the grower to handle his product and agreements and contracts should be faithfully fulfilled by both parties.

The marketing of Colorado lettuce should be considerably improved in the next few years. Better distribution of the crop seems possible and should be investigated. A better-quality product made possible by better-informed growers, together with more strict grading and packing should result in better returns to the grower.

Prices and Yields.—Two large shippers report that the average prices paid the grower in 1922 were $1.50 and $1.64 per crate, respectively, after all packing, transportation and marketing charges were deducted. These prices are considerably lower than those of 1920 and 1921 which, according to one shipper, averaged $2.42 and $2.21 respectively.

In reply to a questionnaire, growers report net prices ranging all the way from $.75 to $2.00 per crate for the 1922 crop.

Yields have been so variable, due to lack of knowledge regarding the crop, weather conditions and other causes, that it is hard to arrive at an average figure. Some have cut 500 or more crates to the acre while others have harvested none at all. Of the 6000 acres reported to have been planted in 1922, probably 5000 acres were cultivated until heads or seed stalks were formed. From this acreage, 827 cars, approximately, were shipped, or a little more than one carload (350 crates) to six acres. This is of course a low average per acre (about sixty crates) but is a warning to those just entering the field not to set the probable yield too high. It would seem that a yield of 200, or possibly 300 crates per acre would not be too much to expect with good soil and favorable weather conditions.

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The Colorado Experiment Station
ENGINEERING DIVISION

REPORT OF ROAD MATERIALS PROJECT

PART 1

By O. V. ADAMS, Testing Engineer

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REPORT OF ROAD MATERIALS PROJECT

PART I

By O. V. ADAMS, Testing Engineer

The demand for improved highways has developed largely as a result of the use and constant increase of motor vehicles for the transportation of passengers and freight. In 1913, the total number of passenger cars and trucks operated in Colorado was 13,135, while in 1922, this number had grown to 151,499 passenger cars and 10,829 trucks, or a total of 162,328 motor vehicles. That the demand for good roads will continue as long as the motor vehicle is a prominent factor in our everyday life, is recognized by all who have studied the problem. The individual citizen, as a taxpayer, may object to the burden of taxation, but he will not cease to demand good roads. The importance of a carefully planned highway program, designed to meet the needs of the traffic and carried out so as to achieve maximum results with a minimum expenditure, is, therefore, evident. A campaign of education by the various road building agencies, to the end that the people will understand the reasons for and the results to be gained from the expenditure of public funds, is of prime importance; otherwise, the taxpayer is liable to lose sight of many of the benefits accruing to the commonwealth as a whole, and to himself as an individual, when he contemplates the taxes which he must pay.

That our progressive urban populations recognize the value of improved roads and streets is evidenced by the fact that in addition to the same state road taxes as are borne by the farm owners, they not only pay for the upkeep of the city streets but expend large sums voluntarily for various forms of street improvements. Some of the advantages to the rural population are as follows: Cheaper and more dependable access to market, increased land values, increased facilities for the development of educational, religious and social life, all of which result in a better rural morale and greater solidarity, which when fully developed will go far toward preventing the movement of the younger generation to towns and cities.

The growth in importance of highway work in the State of Colorado is evidenced by the fact that in 1913 the total expenditure, not counting that of cities and towns, was approximately $2,451,000, while in 1922, the estimated amount available for State and County road construction was approximately $11,389,000. When the expenditures of cities and towns are considered in connection with the above figures, the magnitude of the program is readily seen. The expenditure for materials of construction constitutes 22 percent, in the case of gravel or crushed stone surfaces, and 30 percent, in case of concrete pave-

ment, of the total cost of these improvements, according to estimates made by the Colorado Highway Department. In other words, the total expenditure chargeable to materials was approximately $2,500,000 for 1922. The materials in the State suitable for use in highway construction thus are seen to be of major economic importance.

The principal requirement of any highway program is that it shall, in the shortest possible time and with the least possible expenditure, serve the largest amount of traffic. The ultimate goal of such a program is adequate service of all the traffic needs of county, state, or nation, as the case may be. Adequate service requires a highway roadbed and surface that will serve the traffic at the lowest cost per vehicle-mile.

In arriving at the cost per vehicle-mile, the following items should be considered: Initial cost of improvement, estimated life of surface and salvage value at end of estimated life, annual maintenance cost, annual interest charge, net increase in real estate values because of improved transportation facilities, reduced cost of operation of vehicles because of improvement and total vehicle-miles of traffic per year. Knowing as nearly as possible the traffic to be served, the surface used should be that which will give the lowest cost per vehicle-mile, using local materilas, providing same are known to be of satisfactory quality. If no satisfactory local materials are available, then those which can be laid down on the job at the lowest figure may be used. As an alternative to using imported materials, whose cost is high, it may be possible to secure a lower cost per unit of traffic by using a less permanent type of surface and allowing more for annual maintenance and periodic reconstruction.

A knowledge of the location, quality and quantity of deposits of road material is thus seen to be fundamental in any sound highway program. From a transportation standpoint, the Colorado Highway Department, the road organizations of the counties and public works departments of cities and towns are all affected by the availability of suitable materials. A large amount of construction, other than that related to transportation, is also done by public and private corporations, and private individuals, in which knowledge of available materials is of prime importance.

Having all of these facts in mind and wishing to contribute to the solution of the transportation problems of the State, which are seen to be of great importance to both our rural and urban populations, the officials of the Colorado Experiment Station, Colorado Agricultural College, in 1918, approved the Road Materials Project in the Civil Engineering Section, and ordered the necessary laboratory equipment. This was installed in May, 1919, in the basement of the Civil and Irrigation Engineering building.

The object of the project was to test road materials of Colorado and determine those best suited for surfacing the earth

roads of the State, to construct sample sections of roads surfaced with materials available and secure data wherever possible as to the wearing quality of said materials. In order to further this object, provision was made to allow co-operation with private parties, the State Highway Commission, and the county commissioners of all counties of Colorado.

State and city officials have recognized the value of testing materials to be used in road and street construction and each year has seen an increase in the work done for these officials. All of this work has been done free of charge. However, when samples have been submitted by contractors without certification of the engineer in charge, the actual cost of testing has been collected from the contractor.

The work done during 1919 and 1920 by the testing engineer in charge of the project, who devoted three-fourths of his time to the work, consisted of testing such materials as were sent in by various public officials and private parties throughout the State. Trips over the State were made to locate and sample materials and to acquire a knowledge of general conditions. The materials sampled in the field were then tested in the laboratory and reports sent to all interested parties. A permanent record of results of all tests is on file and copies of such records may be obtained by anyone interested, upon application.

On June 1, 1921, an agreement was entered into between the Highway Department of the State of Colorado and the Engineering Division, Colorado Experiment Station, Colorado Agricultural College, for a co-operative survey of road materials of the State. Under the terms of this agreement, the Highway Department had charge of the field work and samples were tested in the Road Materials Laboratory of the Agricultural College. By mutual understanding, this agreement has continued in effect until the present time. The policy followed has been to first cover the roads where construction was imminent, in order that the information might be used in designing the proposed improvement and estimating its cost. Work of this nature, which was necessarily somewhat scattered, occupied the larger part of the season of 1921. During 1922, the gaps in the 1921 work were filled and a large, continuous mileage of State Highways on the Western Slope was covered.

Approximately 240 deposits have been located, mapped, sampled, and tested under this agreement. These deposits are located in 39 counties and contain approximately 11,500,000 cubic yards of material. Two thousand one hundred and fifty-seven miles, or 61.6 percent, of our State Highways hae been covered by the survey. The work has not been extended to the secondary roads, although many deposits already located may be used on both primary and secondary roads.

The deposits located consist of rock, gravel, and sand for concrete pavement and structures, also rock, gravel, sand and shale for surfacing. These materials were sampled and tested in accordance with standard practice. The Highway Department has been furnished with duplicate copies of all data as soon as tests have been finished.

The accompanying tabulations give the principal data obtained in tests on the materials listed. In Table I, the samples are grouped under the counties in which they are located. For each deposit the following information is given; namely, county reference number, pit number, laboratory serial number, location of deposit by legal subdivision, quantity in deposit and that represented by samples taken, kind of material, purpose for which tested, and remarks.

Table II gives data pertaining to the suitability of material for use in cement concrete. Table III gives data pertaining to the suitability of material for use in various other types of surfacing, such as, water bound Macadam, gravel or sand-clay. Table IV shows data on samples of rock for use either in concrete or as surfacing material, or both.

USE OF TABLES

Knowing the county in which any particular deposit is located, use Table I and find location of deposit, kind of material, and quantity available. To determine quality of material, look under remarks, Table I, and note whether it was tested for use in "C" (concrete) or "Sr" (surfacing). Sand and gravel samples tested for use in concrete are listed in Table II and those for surfacing, in Table III. Table IV shows results of tests upon rock samples, which indicate the suitability of rock for use as concrete aggregate, in Macadam surface or as aggregate for any of the various types of bituminous surfaces or pavements.

If the location or quantity available of any material listed in Tables II, III, or IV is desired, use county reference number of deposit and find county corresponding to this number, after which the desired information is readily obtained from Table I.

ABBREVIATIONS FOR TABLE I

C	Concrete	*	Inclusive
S	Sand	Cl	Clay
Gr.	Gravel	Sh	Shale
		Sr	Surfacing

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. in Pit	Kind of Material	Tested For
Adams	1	2	123 124	N.E.¼, Sec. 13, T. 1 S., R. 67 W.	30,000	30,000	S.&Gr.	C.Sr.
Adams	1	3	129 130	S.E.¼, Sec. 11, T. 1 S., R. 67 W.	2,000	2,000	Gr.&S.	C.Sr.
Adams	1	9	137* 142*	S.E.¼ & N.E.¼, Sec. 8, T. 3 S., R. 68 W.	47,000	47,000	Gr.&S.	C.
Adams	1	10	143 144	S.E.¼, Sec 8, T. 3 S., R. 68 W.	3,000	3,000	Gr.&S.	C.
Adams	1	38	211 212	N.W.¼, Sec. 27 T. 3 S., R. 66 W.	7,500	7,500	S.	C.
Adams	1	70	268	S.W.¼, Sec. 30 T. 3 S., R. 66 W.	9,000	9,000	S.	C.
Arapahoe	3	5	132 133	S.E.¼, Sec. 33 T. 4 S., R. 68 W.	4,000	4,000	Gr.&S.	C.
Arapahoe	3	6	126 136	S.E.¼, Sec. 33 T. 4 S., R. 68 W.	10,000	10,000	S.&Gr.	C.
Arapahoe	3	18	132 133	N.E.¼, Sec. 4 T. 5 S., R. 68 W.	4,000	4,000	S.&Gr.	C.
Arapahoe	3	16	148	N.W.¼, Sec. 4 T. 5 S., R. 68 W.	4,000	4,000	Gr.&S.	C.
Arapahoe	3	17	149 150	N.E.¼, Sec. 5 T. 5 S., R. 68 W.	20,000	20,000	S.&Gr.	C.
Arapahoe	3	19	151	S.W.¼, Sec. 33 T. 4 S., R. 68 W.	2,200	2,200	Gr.&S.	C.
Arapahoe	3	15	152	N.W.¼, Sec. 17 T. 4 S., R. 67 W.	9,000	9,000	S.&Gr.	C.
Arapahoe	3	27	159	N.E.¼, Sec. 5 T. 5 S., R. 68 W.	3,200	3,200	Gr.&S.	C.Sr.
Arapahoe	3	28	160	S.W.¼, Sec. 4 T. 5 S., R. 68 W.	4,500	4,500	S.&Gr.,	C.
Arapahoe	3	25	161 162	N.W.¼, Sec. 32 T. 5 S., R. 68 W.	15,600	15,600	S.&Gr.	C.
Arapahoe	3	71	269	N.E.¼, Sec. 4 T. 4 S., R. 66 W.	6,000	6,000	S.	C.
Archuleta	4		6	7.0 mi from Pagosa Spgs.	Large	Large	Rock	Sr.[1]
Archuleta	4		7	Putman Hill	Large	Large	Rock	Sr.
Archuleta	4		8	Hall Canon	Large	Large	Rock	Sr.
Archuleta	4		9	Stollsteimer Notch	Large	Large	Rock	Sr.
Archuleta	4		10	Yellow Jacket Hill above Squaw Cr.	Large	Large	Rock	Sr.

[1]Wolf Cr. Pass Road

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. Represented in Pit	Kind of Material	Tested For
Archuleta	4		11	14.1 mi from Pagosa Spgs.	1,000	1,000	Gr.&S.	Sr[1]
Archuleta	4		12	San Juan R. West Fork Bridge	2,000	2,000	Gr.&S.	Sr[1]
Archuleta	4		13	0.7 mi. from Pagosa Spgs.	Large	Large	Shale	Sr.[1]
Archuleta	4		14	13.1 mi from Pagosa Spgs.	1,000	1,000	Gr.&S.	Sr.[1]
Archuleta	4	314	502	S.W.¼, Sec. 8 T. 34 N., R. 4 W	10,500	28,000	Gr.&S.	Sr.C.
Archuleta	4	315	504 505	N.W.¼, Sec. 13, T. 35 N., R. 2 W.	22,500	30,000	Gr.&S.	C.Sr.
Archuleta	4	316	506	N.W.¼, Sec. 28, T. 36 N., R. 1 W.	3,500	5,500	Gr.&S.	C.Sr.
Bent	6	225	352	N.W.¼, Sec. 31, T. 22 S., R. 48 W.	5,000	17,500	S.&Gr.	Sr.
Bent	6	226	353	S.W.¼, Sec. 30 T. 22 S., R. 49 W.	2,500	4,500	S.&Gr.	Sr.
Boulder	7	43	89* 99* 43 195	N.E.¼, Sec. 18, T. 3 N., R. 70 W.	Unlim.	Unlim.	Rock	C.
Boulder	7		82 46* 53*	Holmes Quarries near Boulder	Not Known	Not Known	Rock	C.
Boulder	7		61	On St. Vrain R. Near Longmont	2,000	2,000	Gr.&S.	C.[2]
Boulder	7		63	On S. Boulder Cr., Boulder	2,000	2,000	S.&Gr.	C.[3]
Boulder	7	47	83	S.E.¼, Sec. 22 T. 1 N., R. 70 W.	160,000	160,000	Rock	C.
Boulder	7	44	95 96 210	N.W.¼, Sec. 11 T. 2 N., R. 69 W.	1,000	1,000	Rock	C.[4]
Boulder	7	46	236 237	N.W.¼, Sec. 10 T. 2 N., R. 69 W.	9,000	9,000	Gr.&S.	C.
Boulder	7	84	280	N.E.¼, Sec. 10 T. 1 S., R. 69 W.	12,000	12,000	Burnt Shale	Sr.
Boulder	7	48	238	S.E.¼, Sec. 8 T. 1 S., R. 69 W.	6,000	6,000	Burnt Shale	Sr.
Boulder	7	115	328	4½ mi. north of Boulder	Not Known	Not Known	Rock	C.
Boulder	7	227	377 378	S.E.¼, Sec. 10 T. 1 N., R. 69 W.	6,500	11,500	S.&Gr.	C.
Boulder	7	228	379	N.E.¼, Sec. 11 T. 1 N., R. 69 W.	6,000	17,500	Gr.&S.	C.

[1]Wolf Cr. Pass Road
[2]Used on F. A. P. No. 87.
[3]On Wood Farm.
[4]Limestone spalls.

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Quan. in Pit	Kind of Material	Tested For
Chaffee	8	73	274	N.E.¼, Sec. 25 T. 13 S., R. 79 W.	1,000	1,000	Gr.&S.	C.
Chaffee	8	79	275	S.W.¼, Sec. 16 T. 12 S., R. 79 W.	1,200	1,200	Rock & Gr.	C.
Chaffee	8	74	276	N.E.¼, Sec. 11 T. 13 S., R. 79 W	900	900	Gr.&S.	C.
Chaffee	8	75	277	S.E.¼, Sec. 8 T. 14 S., R. 78 W.	700	700	S.&Gr.	C.
Chaffee	8	76	273	S.E.¼, Sec. 8 T. 12 S., R. 79 W.	5,000	5,000	Gr.&S.	C.
Chaffee	8	326	516	N.W.¼, Sec. 15 T. 49 N., R. 9 E.	25,000	50,000	Gr.&S.	Sr.
Delta	15	282	477 478	S.E.¼, Sec. 16 T. 15 S., R. 96 W.	7,000	11,000	Gr.&S.	Sr.C.
Delta	15	283	479	N.E.¼, Sec. 3 T. 15 S., R. 95 W.	10,000	30,000	S.&Gr.	Sr.
Delta	15	284	480	N.E.¼, Sec. 15 T. 15 S., R. 96 W.	10,000	19,500	Gr.&S.	C.Sr.
Delta	15	285	481	N.E.¼, Sec. 13 T. 15 S., R. 96 W.	3,000	6,500	Gr.&S.	C.Sr.
Delta	15	286	482	S.E.¼, Sec. 25 T. 15 S., R. 96 W.	3,000	3,000	Gr.&S.	C.Sr.
Delta	15	287	483	S.W.¼, Sec. 20 T. 51 N., R. 10 W.	2,000	5,000	Gr.&S.	C.Sr.
Denver	16		44	Owned by American Smelting & R. Co.	40,000	40,000	Rock	Sr.[5]
Denver	16		198 145		Not Known	Not Known	S.	C.[6]
Douglas	18	66	259 260	S.W.¼, Sec. 13 T. 6 S., R. 69 W.	75,000	75,000	Gr.&S.	C.
Douglas	18	61	249	S.E.¼, Sec. 14 T. 7 S. R. 68 W.	30,000	30,000	S.&Gr.	C.Sr.
Douglas	18		23	Sec. 1 T. 10 S., R. 68 W.	Large	Large	Rock	Sr.
Douglas	18	62	250	N.E.¼, Sec. 4 T. 7 S., R. 68 W.	9,000	9,000	S.&Gr.	C.Sr
Douglass	18	63	251	S.W.¼, Sec. 23 T. 6 S., R. 68 W.	50,000	50,000	S.&Gr.	C.Sr.
Dougless	18	64	252	S.W.¼, Sec. 17 T. 6 S., R. 68 W.	20,000	20,000	S.&Gr.	C.Sr.
Douglass	18	67	261 262	N.W.¼., Sec. 6 T. 6 S., R. 68 W.	20,000	20,000	Gr.&S.	C.
Douglass	18	68	263 264	S.E.¼, Sec. 32 T. 7 S., R. 68 W.	30,000	30,000	Rock	C.
Douglass	18	26	163	N.W.¼, Sec. 12 T. 6 S., R. 69 W	22,000	22,000	Gr.&S.	C.

[5]Globe Smelter.

[6]Platte R. Sand and Gravel Co.

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Quan. in Pit	Kind of Material	Tested For
Douglass	18	69	266	N.W.¼, Sec. 12 T. 6 S., R. 69 W.	100,000	100,000	Gr.&S.	C.
Eagle	19	251	418	S.½, Sec. 8 T. 4 S., R. 83 W.	27,500	27,500	Rock	Sr.
Eagle	19	252	419	S.E.¼, Sec. 33 T. 4 S., R. 84 W.	8,500	16,500	Gr.&S.	C.Sr.
Eagle	19	252	420	S.W.¼, Sec. 2 T. 5 S., R. 85 W.	4,000	14,500	Gr.&S.	C.Sr.
Eagle	19	254	421	S.E.¼., Sec. 3 T. 5 S., R. 85 W.	3,500	3,500	Gr.&S.	C.Sr.
Eagle	19	255	422 423	N.E.¼, Sec. 4 T. 5 S., R. 86 W.	30,000	52,000	Volcanic Rock&Ash	Sr.
Eagle	19	256	424	S.W.¼, Sec. 32 T. 4 S., R. 86 W.	2,500	4,500	Gr.&S.	C.Sr.
Eagle	19	257	425	N.W.¼, Sec. 12 T. 5 S., R. 86 W.	3,000	3,500	Rock and Clay	Sr.
Eagle	19	258	426	N.W.¼, Sec. 12 T. 5 S., R. 87 W.	2,000	5,500	Gr.&S.	C.Sr.
Elbert	20	205	330	N.E.¼, Sec. 21 T. 10 S., R. 59 W.	3,000	3,000	S.&Gr.	Sr.
Elbert	20	331	42	S.E.¼, Sec. 33 T. 7 S., R. 58 W.	36,000	36,000	Coal Shale	Sr.
El Paso	21	206	329	N.½, Sec. 1 T. 11 S., R. 60 W.	13,000	13,000	S.&Gr.	Sr.
El Paso	21		17	Sec. 10 and 15 T. 14 S., R. 67 W.	Large	Large	Rock	C.Sr.
El Paso	21		19* 21*	Sec. 6 T. 14 S., R. 67 W.	Large	Large	Rock	Sr.
El Paso	21	89	22 296	Sec. 10 and 15 T. 14 S., R. 67 W.	400,000	400,000	Rock	C.Sr.
El Paso	21		33	N.W.¼., Sec. 19 T. 14 S., R. 66 W.	Not Known	Not Known	S.&Gr.	C.[7]
El Paso	21		34	S.E.¼, Sec 20 T. 14 S., R. 66 W.	Not Known	Not Known	S.&Gr.	C.[8]
El Paso	21		35	N.W.¼, Sec. 18 T. 14 S., R. 68 W.	Not Known	Not Known	S.&Gr.	C.[9]
El Paso	21		37	N.W.¼, Sec. 12 T. 14 S., R. 67 W.	Not Known	Not Known	S.&Gr.	C.[10]
El Paso	21		38	N.W.¼, Sec. 6 T. 14 S., R. 66 W.	Not Known	Not Known	S.&Gr.	C.[11]
El Paso	21	50	223 224	N.E.¼, Sec. 4 T. 17 S., R. 65 W.	5,300	5,300	S.&Gr.	C
El Paso	21	59	247	N.E.¼, Sec. 15 T. 17 S., R. 65 W.	11,000	11,000	S.&Gr.	Sr.C.
El Paso	21	60	248	S.W.¼, Sec. 21 T. 16 S., R. 65 W.	24,000	24,000	S.&Gr.	Sr.C.

[7]South Tejon Pit.
[8]Pueblo Road Pit
[9]Monument Cr. Pit
[10]City Pit
[11]Wood Ave. Pit

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Quan. in Pit	Kind of Material	Tested For
El Paso	21	85	256	S.E.¼, Sec. 31 T. 13 S., R. 67 W.	90,000	90,000	Rock	C.Sr.
El Paso	21	88	292	S.E.¼, Sec. 4 T. 14 S. R. 67 W.	2,000	2,000	S.&Gr.	C.
El Paso	21	86	93 294	N.W.¼, Sec. 10 T. 14 S., R. 67 W.	1,500	1,500	S.&Gr.	C.
El Paso	21	87	295	S.E.¼, Sec. 13 T. 14 S., R. 67 W.	1,000	Large	S.	C.
El Paso	21	97	315	S.W.¼, Sec. 5 T. 13 S., R. 66 W.	5,000	5,000	S.	C.
El Paso	21	98	316	S.E.¼, Sec. 7 T. 13 S., R. 66 W.	10,000	10,000	S.	C.
El Paso	21	99	317	S.E.¼, Sec. 19 T. 13 S., R. 66 W.	6,500	6,500	S.&Gr.	C.
El Paso	21	203	331 333	S.E.¼, Sec. 14 T. 12 S., R. 62 W.	13,000	13,000	S.	Sr.
El Paso	21	204	332	N.W.¼, Sec. 14 T. 12 S., R. 62 W.	22,000	22,000	S.&Gr.	Sr.
Fremont	22	211	340	S.E.¼, Sec. 12 T. 19 S., R. 70 W.	12,000	12,000	Rock	Sr.
Fremont	22	111	279	Near Canon City	10,000	10,000	Rock	Sr.
Fremont	22	210	335	Line Sec. 10 & 11 T. 19 S., R. 70 W.	4,000	4,000	Gr.&S.	Sr.
Fremont	22	208	336	S.W.¼, Sec. 34 T. 18 S., R. 70 W.	12,000	12,000	S.Gr.&Cl.	Sr.
Fremont	22	212	337	N.W.¼, Sec. 24 T. 19 S., R. 69 W.	10,500	10,500	Shale	Sr.
Fremont	22	209	338	N.E.¼, Sec. 11 T. 19 S., R. 70 W.	10,000	10,000	S.&Gr.	Sr.
Fremont	22	207	339	N.W.¼, Sec. 32 T. 18 S., R. 70 W.	27,000	27,000	S.&Gr.	Sr.
Fremont	22	213	343 344	S.W.¼, Sec. 24 T. 19 S., R. 68 W.	10,500	10,500	Gr.&S.	C.Sr.
Garfield	23	242	66 67 406	S.W.¼, Sec. 4 T. 6 S., R. 89 W.	75,000	75,000	Rock	C.Sr.
Garfield	23	259	64 427 428	E.½, Sec. 5 T. 6 S., R. 88 W.	4,000	4,000	Rock	Sr.C.[12]
Garfield	23		65	S.W.¼, Sec. 3 T. 6 S., R. 89 W.	5,000	5,000	Rock	Sr.
Garfield	23	260	431	N.E.¼, Sec. 6 T. 6 S., R. 88 W.	10,000	16,500	Rock	Sr.
Garfield	23	261	432	N.E.¼, Sec. 35 T. 5 S., R. 90 W.	30,000	52,000	Gr.&S.	C Sr.
Garfield	23	262	433 434	N.E.¼, Sec. 5 T. 6 S., R. 91 W.	1,500	1,500	S.&Gr.	Sr.

[12]Crushed

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. Represented in Pit	Kind of Material	Tested For
Garfield	23	263	435	N.E.¼, Sec. 11 T. 6 S., R. 91 W.	19,500	35,500	Gr.&S.	C.Sr.
Garfield	23	264	436	N.E.¼, Sec. 10 T. 6 S., R. 91 W.	8,500	30,500	Gr.&S.	C.Sr.
Garfield	23	265	437	S.E.¼, Sec. 10 T. 6 S., R. 93 W.	8,000	20,500	Gr.&S.	C.Sr.
Garfield	23	267	440	S.E.¼, Sec. 35 T. 6 S., R. 95 W.	3,000	6,000	Gr.&S.	C.Sr.
Garfield	23	268	441	S.W.¼, Sec. 12 T. 7 S., R. 96 W.	50,000	71,500	Gr.&S.	C.Sr.
Grand	25	231	387	S.E.¼, Sec. 25 T. 2 N., R. 81 W.	1,500	7,500	S.&Gr.	C.Sr.
Grand	25	232	388	N.W.¼, Sec. 25 T. 2 N., R. 81 W.	3,000	5,500	Gr.&S.	C.Sr.
Grand	25	233	389	S.E.¼, Sec. 12 T. 2 N., R. 81 W.	14,000	21,000	Gr.&S.	C.Sr.
Grand	25	248	407	N.½, Sec. 27 T. 1 S., R. 80 W.	128,000	128,000	Rock	C.Sr.
Grand	25	249	413	N.½, Sec. 9 T. 1 S., R. 80 W.	3,000	7,500	Gr.&S.	Sr.C.
Grand	25	250	414	E.½, Sec. 33 T. 1 N., R. 80 W.	5,000	8,500	Gr.&S.	C.Sr.
Gunnison	26	288	87 484	S.W.¼, Sec. 17 T. 49 N., R. 1 W.	45,000	45,000	Rock	Sr.
Gunnison	26	289	485	Sec. 3 T. 49 N., R. 1 W.	9,500	9,500	Gr.&S.	Sr.C.
Gunnison	26	290	486	Sec. 22 T. 49 N., R. 2 W.	4,500	14,500	S.&Gr.	Sr.
Gunnison	26	291	463	N.E.¼, Sec. 32 T. 49 N., R. 4 W.	4,000	9,500	Gr.&S.	Sr.C.
Gunnison	26	292	470 469	Sec. 11 T .48 N., R. 5 W.	5,500	10,500	Disint. Granite	Sr.
Huerfano	28		2	E.½, Sec. 13 T. 26 S., R. 70 W.	Unlimited	Unlimited	Rock	Sr.
Huerfano	28	352	40	N.W.¼, Sec. 2 T. 26 S., R. 66 W.	258,500	258,500	Rock	Sr.
Huerfano	28		289 301 234 302	S.E.¼, Sec. 4 T. 28 S., R. 66 W.	25,000	750,000	Gr.&S.	C.[13]
Huerfano	28	348	290	N.W.¼, Sec. 8 T. 28 S., R. 66 W.	10,000	90,500	Rock	C.
Jefferson	30	12	170 171 192 193	N.E.¼, Sec. 13 T. 3 S., R. 69 W.	10,000	10,000	Gr.&S.	C.
Jefferson	30	20	153	N.W.¼, Sec. 34 T. 4 S., R. 69 W.	7,900	7,900	Gr.&S.	C.
Jefferson	30	21	154 155	N.W.¼, Sec. 34 T. 4 S., R. 69 W.	28,800	28,800	Gr.&S.	C.

[13]School House Hill

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. Represented in Pit	Kind of Material	Tested For
Jefferson	30	24	156	N.E.¼, Sec. 2 T. 5 S., R. 70 W.	Unlimited	Unlimited	Rock	C.
Jefferson	30	22	157	N.W.¼, Sec. 5 T. 5 S., R. 69 W.	3,500	3,500	Gr.&S.	C.
Jefferson	30	23	158	N.W.¼, Sec. 1 T. 5 S., R. 70 W.	3,200	3,200	Gr.&S.	C.
Jefferson	30	65	257 258	S.E.¼, Sec. 5 T. 6 S., R. 69 W.	30,000	30,000	Rock	C.
Jefferson	30	80	281* 283*	N.E.¼, Sec. 33 T. 4 S., R. 69 W.	8,000	8,000	S.&Gr.	C.
Jefferson	30	81	284 285	N.E.¼, Sec. 33 T. 4 S., R. 69 W.	2,900	2,900	S.&Gr.	C.
Jefferson	30	82	286 287	N.E.¼, Sec. 34 T. 4 S., R. 69 W.	2,000	2,000	S.&Gr.	C.
Jefferson	30	83	288	S.E.¼, Sec. 32 T. 4 S., R. 69 W.	3,000	3,000	S.&Gr.	C.
Jefferson	30	49	239	N.E.¼, Sec. 3 T. 2 S., R. 69 W.	19,000	19,000	Gr.&S.	Sr.
Jefferson	30	202	324	N.W.¼, Sec. 34 T. 5 S., R. 70 W.	2,000	2,000	Rock	C.
La Plata	34	305	465	N.W.¼, Sec. 10 T. 35 N., R 11 W.	14,500	34,500	Gr.& Rock	Sr.
La Plata	34	306	466	N.E.¼, Sec. 23 T. 35 N., R. 11 W.	12,000	25,000	Gr.&S.	C.Sr.
La Plata	34	307	462	S.W.¼, Sec. 25 T. 35 N., R. 11 W.	5,500	13,500	Gr.&S.	Sr.
La Plata	34	308	15 467 468	W.½, Sec. 30 T. 35 N., R. 9 W.	107,000	107,000	Gr.&S.	C.Sr.
La Plata	34	309	497	N.E.¼, Sec. 31 T. 37 N., R. 8 W.	13,500	22,500	Gr.&S.	C.Sr.
La Plata	34	310	498	S.W.¼, Sec. 17 T. 35 N., R. 9 W.	7,500	17,500	Gr.&S.	Sr.
La Plata	34	311	499	S.W.¼, Sec. 16 T. 35 N., R. 9 W.	30,000	55,000	S.Gr.&Cl.	Sr.
La Plata	34	312	500	S.E.¼, Sec. 9 T. 34 N., R. 9 W.	12,500	26,500	Gr.&S.	Sr.
La Plata	34	313	501	S.W.¼, Sec. 11 T. 34 N., R. 7 W.	7,000	15,500	Gr.&S.	C.Sr.
Larimer	35		56 57	Pearlman Pit near Loveland	800	800	Gr.&S.	C.[14]
Larimer	35		68	Near Loveland	2,500	2,500	S.&Gr.	C.[15]
Larimer	35	8	74* 81* 245	N.E.¼, Sec. 2 T. 6 N., R. 70 W.	Unlimited	Unlimited	Rock	C.
Larimer	35		84	N.W.¼, Sec. 30 T. 9 N., R. 69 W.	Large	Large	Rock	C.

[14]Pit Exhausted

[15]Sprague-Anderson Farm

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Quan. in Pit	Kind of Material	Tested For
Larimer	35		85	N.W.¼, Sec. 30 T. 9 N., R. 69 W.	Large	Large	Rock	C.
Larimer	35		4	In Big Thompson Canon	1,000	1,000	Rock	C.Sr.
Larimer	35	7	86 86a 109 134	S.E.¼, Sec. 3 T. 7 N., R. 69 W.	60,000	60,000	Gr.&S.	C.
Larimer	35	45	189	N.E.¼, Sec. 13 T. 5 N., R. 69 W.	3,000	3,000	Rock	C.
Larimer	35	42	190 191	S.E.¼, Sec. 35 T. 7 N., R. 69 W.	18,600	18,600	S.&Gr.	Sr.
Larimer	35	41	221 222	S.E.¼, Sec. 36 T. 7 N., R. 68 W.	72,000	72,000	Gr.&S.	C.Sr.
Larimer	35		254 265	S.W.¼, Sec. 33 T. 9 N., R. 70 W.	2,000	2,000	Gr.&S.	C.[16]
Larimer	35		235	N.E.¼, Sec. 12 T. 7 N., R. 69 W.	3,000	3,000	Rock	C.
Larimer	35		404	S.W.¼, Sec. 27 T. 7 N., R. 68 W.	3,000	3,000	Gr.&S.	C.
Larimer	35	90	297 298	N.E.¼, Sec. 4 T. 6 N., R. 68 W.	3,500	3,500	Gr.&S.	C.Sr.
Larimer	35	91	57 299 300 326 348 349	N½W.¼, Sec. 28 T. 7 N., R 68 W.	10,000	10,000	Gr.&S.	C.
Larimer	35		354 107 146 305* 307*	N.E.¼, Sec. 18 T. 7 N., R. 68 W.	5,000	5,000	Gr.&S.	C.[17]
Larimer	35		318	S.E.¼, Sec. 3 T. 8 N., R. 69 W.	5,000	5,000	Gr.&S.	C.[18]
Larimer	35		334 345* 347*	N.W.¼, Sec. 15 T. 5 N., R. 69 W.			Gr.&S.	C.Sr.[19]
Larimer	35	118	372	1½ mi. west of Loveland	Not Known	Not Known	Gr.&S.	C.[20]
Larimer	35	229	380	S.W.¼, Sec. 27 T. 9 N., R. 68 W.	10,000	30,000	S.&Gr.	Sr.
Larimer	35	230	381	S.E.¼, Sec. 34 T. 10 N., R. 68 W.	15,000	45,500	S.&Gr.	Sr.

[16]Fort Collins Filter Plant
[17]Clammer Pit
[18]Bingham Hill
[19]Chamberlain Pit
[20]Lund Pit

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. Represented in Pit	Kind of Material	Tested For
Larimer	35		415	E.½, Sec. 20 T. 5 N., R. 68 W.	5,000	100,000	S.&Gr.	C.
Larimer	35		417	N.E.¼, Sec. 3 T. 6 N., R. 68 W.	5,000	100,000	Gr.&S.	C.
Las Animas	36		29	S. E. of Thatcher	Unlimited	Unlimited	Rock	Sr.
Las Animas	36		30	S. of Wooten on State line	Unlimited	Unlimited	Rock	Sr.
Las Animas	36		180 205	S.W.¼, Sec. 26 T. 33 S., R. 67 W	Not Known	Not Known	S.	C.
Las Animas	36		200 201 253	Sec. 7 T. 33 S., R. 63 W.	Not Known	Not Known	S.	C.
Las Animas	36		202	1000 ft. west of City Hall, Trinidad	Not Known	Not Known	S.	C.
Logan	38	14	147	N.W.¼, Sec. 34 T. 8 N., R. 52 W.	Unlimited	Unlimited	S.&Gr.	C.
Logan	38	95	311* 313*	E.½, Sec. 31 T. 9 N., R. 52 W.	10,000	10,000	S.&Gr.	C.
Logan	38	96	314	N.E.¼, Sec. 33 T. 6 N., R. 54 W.	22,000	22,000	S.&Gr.	C.Sr.
Mesa	39	269	442	N.E.¼, Sec. 23 T. 8 S., R. 97 W.	5,000	8,000	Gr.&S.	C.Sr.
Mesa	39	270	443	N.E.¼, Sec. 27 T. 8 S., R. 97 W.	7,000	19,000	Gr.&S.	C.Sr.
Mesa	39	271	444	N.W.¼, Sec. 8 T. 10 S., R. 96 W.	5,000	13,000	Gr.&S.	Sr.
Mesa	39	272	445	S.W.¼, Sec. 11 T. 10 S., R. 97 W.	4,000	8,000	S.&Gr.	C.Sr.
Mesa	39	273	446	N.W.¼, Sec. 34 T. 10 S., R. 98 W.	12,000	20,000	Gr.&S.	C.Sr.
Mesa	39	274	451	S.W.¼, Sec. 7 T. 1 S., R. 2 E.	10,000	16,000	Gr.&S.	C.Sr.
Mesa	39	275	452 453	N.W.¼, Sec. 23 T. 1 S., R. 1 E.	6,000	19,000	Gr.S.&Sh.	Sr.
Mesa	39	276	454	Center, Sec. 8 T. 1 S., R. 1 W.	22,500	72,500	Gr.&S.	C.Sr.
Mesa	39	277	455 456	S.E.¼, Sec. 23 T. 1 S., R. 1 W.	26,500	26,500	Gr.&S.	C.Sr.
Mesa	39	278	457	N.W.¼, Sec. 33 T. 9 S., R. 104 W.	30,000	51,500	Rock	C.Sr.
Mesa	39	279	458	N.W.¼, Sec. 29 T. 1 N., R. 2 W.	9,000	14,000	Gr.&S.	Sr.
Mesa	39	280	459	S.W.¼, Sec. 20 T. 1 N., R. 2 W.	20,000	46,000	Gr.&S.	C.Sr.
Mesa	39	281	460	S.W.¼, Sec. 3 T. 1 N., R. 3 W.	30,000	65,000	Gr.&S.	Sr.
Mineral	40	116	374 375	N.E.¼, Sec. 35 T. 40 N., R. 1 E.	300,000	300,000	Rock	Sr.
Moffatt	41	236	392	S.½, Sec. 23 T. 4 N., R. 93 W.	15,000	50,000	Gr.&Sh.	Sr.

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Quan. in Pit	Kind of Material	Tested For
Moffatt	41	237	393 394	N.E.¼, Sec. 3 T. 6 N., R. 91 W.	23,000	23,000	Gr.&S.	C.Sr.
Moffatt	41	238	395	N.E.¼, Sec. 5 T. 6 N., R. 90 W.	9,000	14,500	Gr.&S.	C.
Montezuma	42	110	218	S.E.¼, Sec. 22 T. 37 N., R. 15 W.	40,000	40,000	Rock	Sr.
Montezuma	42	300	494	N.E.¼, Sec. 17 T. 37 N., R. 15 W.	5,500	5,500	Gr.&S.	C.Sr.
Montezuma	42	301	495	N.E.¼, Sec. 2 T. 35 N., R. 14 W.	7,000	11,000	Gr.&Cl.	Sr.
Montezuma	42	302	496	N.W.¼, Sec. 29 T. 36 N., R. 13 W.	2,000	7,500	Gr.&S.	C.Sr.
Montezuma	42	303	464	N.W.¼, Sec. 26 T. 36 N., R. 13 W.	4,000	8,500	Gr.&S.	C.Sr.
Montezuma	42	304	461	S.E.¼, Sec. 30 T. 36 N., R. 12 W.	18,000	31,000	Gr.S.&Cl.	Sr.
Montrose	43		18 27	Sec. 33 T. 49 N., R. 9 W.	50,000	50,000	S.&Gr.	Sr.
Montrose	43		70* 73*	S.W.¼, Sec. 30 T. 49 N. ,R. 9 W.	25,000	25,000	Gr.&S.	Sr.[21]
Montrose	43	296	490	S.W.¼, Sec. 10 T. 48 N., R. 9 W.	5,000	13,500	Gr.&S.	C.Sr.
Montrose	43	297	491	S.E.¼, Sec. 7 T. 47 N, R. 8 W.	4,000	7,000	Gr.&S.	C.Sr.
Montrose	43	294	488	Sec. 25 T. 49 N., R. 8 W.	30,000	30,000	Gr.&S.	C.Sr.
Montrose	43	295	489	S.W.¼, Sec. 28 T. 49 N., R. 9 W.	4,000	6,000	Gr.&S.	C.Sr.
Montrose	43	293	487	Sec. 3 T. 48 N., R. 7 W.	5,500	5,500	Disint. Granite	Sr.
Morgan	44	93	308	N.W.¼, Sec. 31 T. 4 N., R. 57 W.	5,500	5,500	S.&Gr.	C.Sr.
Morgan	44	94	309 310	N.E.¼, Sec. 19 T. 4 N., R. 57 W.	30,000	30,000	Gr.S.&Cl.	C.Sr.
Morgan	44		115	Fort Morgan	Not Known	Not Known	Rock	C.[22]
Morgan	44		267	3½ mi. N. of Brush, Colorado	Unlimited	Unlimited	S.&Gr.	C.
Otero	45	54	231* 233*	N.E.¼, Sec. 31 T. 23 S., R. 55 W.	46,000	46,000	S.&Gr.	C.
Otero	45	55	240 241	N.W.¼, Sec. 15 T. 22 S., R. 59 W.	60,000	60,000	Gr.&S.	C.
Otero	45	216	355	Sec. 33 T. 27 S., R. 59 W.	8,000	15,500	Gr.&S.	Sr.
Otero	45	217	356 357	S.E.¼, Sec. 34 T. 25 S., R. 57 W.	6,500	6,500	S.&Gr.	C.Sr.
Otero	45	218	358	N.E.¼, Sec. 24 T. 25 S., R. 57 W.	8,000	8,000	LimeSh.	Sr.

[21]Crushed

[22]Great W. Sug. Co. Spalls

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. in Pit	Kind of Material	Tested For
Otero	45	219	376	N.W.¼, Sec. 2 T. 25 S., R. 56 W.	3,500	7,000	Lime Sh.	Sr.
Otero	45	220	359	N.E.¼, Sec. 35 T. 23 S., R. 55 W.	17,000	17,000	Rock	C.
Otero	45	221	360* 362*	N.W.¼, Sec. 30 T. 23 S., R. 55 W.	9,000	9,000	S.&Gr.	C.
Otero	45	222	363 364	N.E.¼, Sec. 24 T. 23 S., R. 55 W.	13,000	18,500	Gr.&S.	C.
Ouray	46	299	493	N.E.¼, Sec. 16 T. 45 N., R. 8 W.	6,000	12,500	Gr.&S.	C.Sr.
Ouray	46	298	492	S.E.¼, Sec. 5 T. 46 N., R. 8 W.	2,000	3,500	Gr.&S.	C.Sr.
Park	47	77	271	N.E.¼, Sec. 27 T. 12 S., R. 72 W.	600	600	Rock	C.
Park	47	78	272	S.W.¼, Sec. 22 T. 12 S., R. 72 W.	700	700	Rock	C.
Park	47	79	270	S.E.¼, Sec. 19 T. 12 S., R. 71 W.	8,000	8,000	Gr.&S.	C.
Prowers	50	101	181	N.W.¼, Sec. 25 T. 22 S., R. 47 W.	20,000	20,000	S.&Gr.	C.Sr.
Prowers	50	102	182	S.E.¼, Sec. 19 T. 22 S., R. 47 W.	10,000	10,000	Gr.&S.	Sr.
Prowers	50	103	183	N.W.¼, Sec. 30 T. 22 S., R. 46 W.	6,000	6,000	Gr.&S.	C.Sr.
Prowers	50	104	184	N.E.¼, Sec. 21 T. 22 S., R. 46 W.	5,000	5,000	Gr.&S.	Sr.
Prowers	50	105	185	N.E.¼, Sec. 17 N.W.¼, Sec. 16 T. 22 S., R. 47 W.	50,000	50,000	Gr.&S.	Sr.
Prowers	50	106	186	N.W.¼, Sec. 31 T. 22 S., R. 44 W.	6,500	6,500	Gr.&S.	C.Sr.
Prowers	50	107	187	N.E.¼, Sec. 15 T. 23 S., R. 44 W.	17,000	17,000	Sh.	Sr.
Prowers	50	108	188	S.W.¼, Sec. 30 T. 22 S., R. 43 W.	15,000	15,000	Gr.&S.	Sr.
Prowers	50	223	350	S.E.¼, Sec. 11 T. 23 S., R. 41 W.	8,000	15,000	S.&Gr.	C.Sr.
Prowers	50	224	351	N.W.¼, Sec. 6 T. 23 S., R. 42 W.	9,500	16,500	S.&Gr.	C.Sr.
Pueblo	51	58	246	N.E.¼, Sec. 2 T. 18 S., R. 65 W.	5,000	5,000	S.&Gr.	C.Sr.
Pueblo	51		39	Sec. 11 T. 22 S., R. 65 W.	Unlimited	Unlimited	Rock	Sr.C.
Pueblo	51	57	94 164 178	S.E.¼, Sec. 33 S.W.¼, Sec. 34 T. 20 S., R. 66 W.	1,700,000	1,700,000	Rock	C.Sr.
Pueblo	51	52	203 203a 227* 229*	N.W.¼, Sec. 31 T. 20 S., R. 64 W.	3,000	Ample	S.&Gr.	C.

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Quan. in Pit	Kind of Material	Tested For
Pueblo	51	51	225 226	S.E.¼, Sec. 6 T. 21 S., R. 63 W.	11,300	11,300	S.&Gr.	C.
Pueblo	51	53	230	N.W.¼, Sec. 1 T. 21 S., R. 64 W.	10,000	10,000	S.&Gr.	C.
Pueblo	51	56	242* 244*	S.½, Sec. 3 T. 22 S., R. 60 W.	910,000	910,000	S.&Gr.	C.Sr.
Pueblo	51	215	341	S.E.¼, Sec. 21 T. 22 S., R. 65 W.	13,500	13,500	Rock	C.
Pueblo	51	214	342	N.E.¼, Sec. 21 T. 22 S., R. 65 W.	3,000	3,000	S.	C.
Rio Blanco	52	234	390	N.E.¼, Sec. 24 T. 1 N., R. 94 W.	87,500	87,500	Gr.&S.	C.Sr.
Rio Blanco	52	235	391	S.½, Sec. 20 T. 1 N., R. 93 W.	24,500	24,500	Sh.&S.	Sr.
Rio Blanco	52	239	396	E.½, Sec. 2 T. 1 N., R. 94 W.	3,000	6,500	Gr.&S.	C.Sr.
Rio Blanco	52	240	397	N.W.¼, Sec. 1 T. 1 N, R. 97 W.	5,000	5,000	Gr.&S.	C.Sr.
Rio Blanco	52	241	398 399	S.½, Sec. 28 T. 1 N., R. 94 W.	12,000	12,000	Sh.	Sr.
Rio Blanco	52	266	438 439	S.W.¼, Sec. 5 T. 4 S., R. 94 W.	30,000	69,000	Oil Sh.	Sr.
Rio Grande	53	317	507	N.E.¼, Sec. 28 T. 40 N., R. 5 E.	7,500	7,500	Rhyolite and Shale	Sr.
Rio Grande	53	318	508	N.E.¼, Sec. 18 T. 39 N., R. 7 E.	17,500	37,500	Rhyolite Gr.S.&Cl.	Sr.
Rio Grande	53	319	509	S.E.¼, Sec. 6 T. 39 N., R. 7 E.	10,000	17,500	Gr.&S.	C.Sr.
Rio Grande	53	320	510	N.E.¼, Sec. 24 T. 39 N., R. 7 E.	6,500	11,500	Gr.&S.	C.Sr.
Saguache	55		98	North of Gibson	Large	Large	S.	Sr.[23]
Saguache	55		99	North of Gibson	Not Known	Not Known	Adobe	Sr.[23]
Saguache	55		100	North of Gibson	Not Known	Not Known	S.	Sr.[23]
Saguache	55		101	LaGarita Saguache Cr. Bottoms	Not Known	Not Known	S.&Cl.	Sr.[23]
Saguache	55		102	S. Side of Morgan's Ranch	Large	Large	Top Soil	Sr.
Saguache	55		117	E. Side of G. V. Rudd Ranch	Large	Large	S.&Cl.	Sr.
Saguache	55		118	La Garita Cr.	Not Known	Not Known	S.&Cl.	Sr.[24]
Saguache	55		119	La Garita Cr.	Not Known	Not Known	S.&Cl.	Sr.[24]
Saguache	55		405	Sta. 259 State Highway Project 119-B	Not Known	Not Known	Rock	Sr.

[23]Hooper-Moffat Road [24]Poor Material

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. in Pit	Kind of Material	Tested For
Saguache	55		449	Sta. 113 State Highway Project 119-B	Not Known	Not Known	Rock	Sr.
Saguache	55		450	Sta. 158 State Highway Project 119-B	Not Known	Not Known	Rock	Sr.
Saguache	55	321	511	S.E.¼, Sec. 24 T. 45 N., R. 6 E.	12,000	25,500	Disint. Granite	Sr.
Saguache	55	322	512	S.E.¼, Sec. 17 T. 45 N., R. 6 E.	500	1,500	Gr.&S.	C.Sr.
Summit	59	243	408	W.½, Sec. 28 T. 3 S., R. 76 W.	5,000	17,000	Gr.&S.	C.Sr.
Summit	59	244	409	N.½, Sec. 29 T. 3 S., R. 78 W.	4,000	9,000	Gr.&S.	C.Sr.
Summit	59	245	410	S.E.¼, Sec. 1 T. 3 S., R. 79 W.	3,000	10,500	Gr.&S.	C.Sr.
Summit	59	246	411	N.E.¼, Sec. 29 T. 2 S., R. 79 W.	1,500	1,500	Gr.&S.	C.Sr.
Summit	29	247	412	W.½, Sec. 19 T. 2 S., R. 79 W.	5,000	20,000	Gr.&S.	C.Sr.
Teller	60		31a	Portland Gold	150,000	150,000	Rock	C.Sr.
			36	M. Co., Victor				
Teller	60		25	S.E.¼, Sec. 20	150,000	150,000	Rock	C.
			319	T. 15 S., R. 69 W.				
			320					
Teller	60	201	321	S.E.¼, Sec. 20	1,000,000	1,000,000	Rock	C.
			322	T. 15 S., R. 69 W.				
Weld	62	1	122	S.E.¼, Sec. 18 T. 1 N., R. 67 W.	50,000	50,000	S.&Gr.	C.
Weld	62	4	131	N.E.¼, Sec. 25 T. 1 N., R. 67 W.	2,000	2,000	Gr.&S.	C.
Weld	62	32	165	N.E.¼, Sec. 12 T. 2 N., R. 67 W.	13,800	13,800	Gr.&S.	C.Sr.
Weld	62	33	166	N.W.¼, Sec. 30 T. 3 N., R. 66 W.	8,300	8,300	S.&Gr.	C.Sr
Weld	62	34	167	N.W.¼, Sec. 6	8,500	8,500	S.Gr.&Cl.	C.Sr.
			168	T. 3. N., R. 66 W.				
Weld	62	35	169	S.W.¼, Sec. 17 T. 4 N., R. 66 W.	16,600	16,600	S.&Gr.	Sr.
Weld	62	29	172	S.W.¼, Sec. 19 T. 2 N., R. 66 W.	8,000	8,000	S.&Gr.	Sr.
Weld	62	30	173	S.W.¼, Sec. 17 T. 2 N., R. 66 W.	11,800	11,800	S.&Gr.	C.Sr.
Weld	62	31	174	S.W.¼, Sec. 17 T. 2 N., R. 66 W.	11,500	11,500	S.&Gr.	C.Sr.
Weld	62	36	175	S.W.¼, Sec. 9 T. 4 N., R. 66 W.	13,600	13,600	S.&Gr.	C.Sr.
Weld	62	37	176	S.E.¼, Sec. 31 T. 5 N., R. 65 W.	31,300	31,300	S.&Gr.	C.Sr.
Weld	62	39	213*	S.W.¼, Sec. 31	48,000	48,000	S.&Gr.	C.
			216*	T. 6 N., R. 65 W.				

TABLE NO. 1—GENERAL REFERENCE

County	Co. Ref. No.	Pit No.	Serial No.	Location or Legal Subdivision	Approx. Quan. Represented by Sample	Approx. Quan. in Pit	Kind of Material	Tested For
Weld	62	40	103 219 220 111	N.E.¼, Sec. 29 T. 6 N., R. 67 W.	26,000	26,000	Gr.&S.	C.
Weld	62	92	303 304	N.W.¼, Sec. 11 T. 5 N., R. 65 W.	16,000	16,000	Gr.&S.	C.

ABBREVIATIONS FOR TABLE II

W. O. K......**Washed sand O. K.**
W. N. G.....**Washed sand not good**
Ref. ..... **Reference**
Str. ..... **Strength**
Stan. ..... **Standard**
Approx. ..... **Approximately**

TABLE NO. 2—MATERIAL TESTED FOR USE AS CONCRETE

Co. Ref. No.	Serial No.	GRAVEL Percent		GRAVEL Percent Retained on Screen			GRAVEL Compress. Strength 1 : 2 : 3 Concrete lbs. per sq. inch	GRAVEL Wt. per cu. foot	SAND Percent Retained on Sieve		SAND Percent Passing Sieve	SAND Silt	SAND Tensile Test 1 : 3 Mortar Ratio to Standard Sand		SAND Weight per cubic foot	SAND Organic Content parts per million	Remarks
		Sand	Gravel	3 in.	2 ½ in.	1 in.			20	50	100		7 days	28 days			
43	18	43	57	0	2	42			32	66	11.8	1.2	.61	.86		OK	
43	27	100							35	64	11.4	1.2	1.04	1.09		OK	
60	36	0		0	0	10	3370										[1]
21	33	83	17	0	0	11			54	79	8.1	1.7	1.33	1.08	108	OK	
21	34	71	29	0	0	8			79	88	8.0	4.9	1.12	1.02		OK	
21	35	92	8	0	0	0			56	89	2.1	0.4	1.51	1.22		OK	
21	37	64	36	0	0	5			69	88	5.9	3.1	1.33	1.06		OK	
21	38	85	15	0	0	0			72	93	4.4	3.5	1.15	1.09		OK	
35	56	97	3						56	92	3.2	1.7	1.39	1.21		OK	
35	57	90	10						47	90	3.3	1.3	1.40	1.06		OK	
7	61	32	68		10	64			62	87	4.3	2.0	1.14	1.09		OK	
7	63	100	0						81	94	2.2	0.7	1.55	1.23		OK	
35	68			3	11	51			46	88	4.7	1.6	1.29	1.06		OK	[2]
7	82	100	0						29	66	13.6	0.0	0.86	0.86		OK	[3]
7	83	100	0						86	94	3.2	0.0	1.62	1.67		OK	[4]
35	84	100	0						41	62	5.4	0.0	1.06	1.08		OK	[4]
35	85	52	48						49	83	6.8	0.0	1.52	1.44		OK	[5]
35	146	54	46	5	14	43	2680		36	78	5.4	1.2	1.25	1.22	107	OK	
35	86A					24			56	86	6.8	3.6	1.16	1.03		OK	
21	93	85	15	0	0	0			49	82	7.1	3.4	1.20	1.13		OK	
62	103	54	46	0	13	46			47	88	2.9	1.1	1.16	1.08		OK	
35	107	97	3	0	0	0			15	76	6.3	0.7	1.08	0.99		OK	
35	109	86	14	0	0	0			73	95	2.2	1.0	1.34	1.34		OK	
62	111	40	60	9	24*	57			45	91	3.8	1.7	1.27	1.12		OK	
62	122	74	26	0	0	8	2600	107	56	87	2.7	0.5	1.58	1.31	107	OK	

[1]Comp. mix 1:4.5 sand No. 33 [2]Large amount mica [3]Fines from crusher [4]Fines made in Lab.
[5]Conglomerate tested for sand *Commencing with this sample, this column shows percentage retained on 2" screen.

TABLE NO. 2—MATERIAL TESTED FOR USE AS CONCRETE

Co. Ref. No.	Serial No.	GRAVEL Percent		GRAVEL Percent Retained on Screen			GRAVEL Compress. Strength 1:2:3 Concrete lbs. per sq. inch	GRAVEL Wt. per cu. foot	SAND Percent Retained on Sieve		SAND Percent Passing Sieve	SAND Silt	SAND Tensile Test 1:3 Mortar Ratio to Standard Sand		Weight per cubic foot	Organic Content parts per million	Remarks
		Sand	Gravel	3 in.	2 in.	1 in.			20	50	100		7 days	28 days			
1	123	66	34	0	8	28	2385	107	50	87	2.0	0.7	1.45	1.21	107	OK	
1	124	70	30	0	14	31		107	44	79	6.0	2.0	1.49	1.20	107	OK	
3	126	52	48	24	49	68	2330	105	85	97	2.3	2.3	1.36	1.18	100	OK	
1	129	36	64	31	44	73	2320	106	49	71	16.6	9.3	0.84	0.86	107	OK	
1	130	36	64	32	43	65		106	65	83	10.6	7.3	1.02	1.00	104	OK	
62	131	46	54	0	0	32	2365	104	50	91	1.5	0.4	1.20	1.16	110	OK	
3	132	58	42	0	4	46	2440	104	55	94	1.6	1.4	1.20	1.16	104	OK	
3	133	38	62	28	42	74	2440	103	63	89	4.6	2.6	1.27	1.15	106	OK	
35	134	17	83	26	39	76	2730	106	62	91	4.3	0.9	1.34	1.34	105	OK	
3	136	57	43	0	0	41		105	40	84	5.2	1.3	1.41	1.13	106	OK	
1	137	31	69	26	51	74	2590	105	39	84	5.0	1.4	1.10	0.96	108	500	
1	138	28	72	15	34	79	2590	105	23	78	5.3	1.0	1.20	1.02	105	350	
1	139	46	54	29	44	73	2590	105	22	74	5.1	0.6	1.06	0.92	104	500	
1	140	48	52	26	37	72	1970	105	28	85	2.2	0.4	0.92	0.87	102	OK	
1	141	43	57	9	20	60	1970	104	26	52	15.5	1.8	0.83	0.78	105	500	W.O.K.
1	142	42	58	9	27	69	1970	105	24	72	8.2	1.7	0.97	0.84	103	1500	W.N.G.
1	143	28	72	13	30	62	2380	106	42	79	8.5	3.3	1.13	0.91	105	OK	
1	144	26	74	32	52	77	2380	106	42	79	7.4	4.9	0.89	0.81	104	OK	W.N.G.
16	145	100	0						40	89	2.3	1.2	1.16	1.22	102	OK	
38	147	87	13	0	0	8	2660	100	44	89	1.6	0.4	1.45	1.18	110	OK	
3	148	32	68	10	27	72	2440	104	29	57	16.8	2.0	1.13	1.06	111	500	W.O.K.
3	149	84	16	0	0	2		104	25	74	4.0	1.4	1.20	1.00	103	1000	W.N.G.
3	150	33	67	9	18	58	2270	105	44	78	7.9	2.8	1.16	0.99	111	500	W.O.K.
3	151	36	64	8	28	74	2240	106	61	92	3.2	2.0	1.55	1.20	102	OK	
3	152	90	10	0	0	0			70	93	2.7	1.8	1.56	1.27	100	OK	

30	153	38	62	10	29	63	2360	102	29	68	10.1	2.6	1.01	0.93	105	500	W.O.K.
30	154	39	61	29	46	73	2170	101	38	67	18.0	7.0	0.91	0.83	106	1000	W.N.G.
30	155	31	69	45	63	83		103	25	47	29.9	9.7	0.60	0.81	99	1000	W.N.G.
30	157	31	69	59	72	84	1890	103	43	76	9.7	4.2	0.72	0.85	101	1000	W.N.G.
30	158	39	61	19	36	64	2590	102	58	91	2.9	0.9	1.45	1.35	103	OK	
3	159	30	70	23	41	76	2525	101	45	78	11.5	5.4	1.11	1.05	105	500	W.N.G.
3	160	53	47	0	20	57	2625	104	63	93	2.4	1.4	1.37	1.10	102	OK	
3	161	77	23	0	0	5			49	76	11.6	3.2	1.04	0.92	110	200	
3	162	44	56	0	18	55	2675	105	47	72	16.5	8.1	0.90	0.92	109	100	W.O.K.
18	163	30	70	47	69	84	2500	103	59	81	10.3	3.6	1.09	1.14	108	50	W.O.K.
62	165	61	39	0	7	28	2970	102	52	92	1.4	0.6	1.25	1.11	109	25	
62	166	87	13	0	0	0			51	87	2.9	0.3	1.30	1.07	109	0	
62	167	74	26	0	0	5			47	84	4.1	0.9	1.36	1.17	107	25	
1	170	36	64	4	29	74	2640	103	32	68	14.3	4.0	0.85	0.86	107	350	
1	171	100	0						47	82	6.2	2.1	1.00	1.01	109	300	
62	172	66	34	0	0	8	2990	98	57	91	2.3	0.7	1.25	1.10	110	50	
62	173	79	21	0	0	8		96	51	82	7.6	3.9	1.17	0.96	103	25	W.O.K.
62	174	64	36	0	0	18	2990	99	53	82	7.3	4.0	0.90	0.95	108	50	W.O.K.
62	175	80	20	0	0	4	2460	96	52	88	4.0	1.3	1.21	0.98	106	10	
62	176	76	24	0	0	0	3000	97	55	87	4.0	1.7	1.22	1.08	105	0	
51	178	4	96	0	0	62	3070	85									
36	180	88	12						37	84	5.5	2.2	1.19	1.21		150	
50	181	71	29	0	0	10	3150	100	50	85	3.4	0.8	1.47	1.39	111	0	
50	183	34	66	3	15	67	2890	107	39	84	5.4	2.4	1.37	1.17	108	0	
50	186	66	34	0	6	60	2645	101	41	79	6.7	1.6	1.26	1.10	111	0	
35	189	7	93	31	59	82	3660										
1	192	40	60	14	32	61		103	33	72	10.4	3.9	0.93	1.07	107	1500	
1	193	93	7						43	78	7.5	2.3	0.99	1.06	108	800	
1	195	1	99	0	0	67	4110	86									
7	195	1	99	0	0	67	4110	86									
16	198	100	0						48	87	3.3	1.1	1.13	1.07	105	0	
36	200	100	0						36	67	13.8	3.9	0.89	1.00		200	Washed
36	201	100	0						31	68	15.3	6.1	0.91	1.07			
36	202	93	7						27	75	11.7	4.2	0.84	0.97		500	
51	203	100	0						77	92	4.4	2.1	1.23	1.03		100	

TABLE NO. 2—MATERIAL TESTED FOR USE AS CONCRETE

Co. Ref. No.	Serial No.	GRAVEL Percent Sand	GRAVEL Percent Gravel	GRAVEL Percent Retained on Screen 3 in.	2 in.	1 in.	GRAVEL Compress. Strength 1:2:3 Concrete lbs. per sq. inch	GRAVEL Wt. per cu. foot	SAND Percent Retained on Sieve 20	50	SAND Percent Passing Sieve 100	SAND Silt	SAND Tensile Test 1:3 Mortar Ratio to Standard Sand 7 days	28 days	SAND Weight per cubic foot	SAND Organic Content parts per million	Remarks
51	203A	100	0						68	97	0.7	0.1	1.33	1.25		0	
36	205	88	12						37	84	5.5	2.2	1.19	1.21		150	
7	210	6	94	24	53	83	3340										
1	211	100	0						7	62	8.5	1.8	0.85	0.81	97	0	
1	212	100	0						6	66	7.4	2.1	0.91	0.84	96	20	
62	213	50	50	0	13	56	3205	108	48	90	2.8	0.8	1.32	1.11	106	15	
62	214	62	38	0	0	41	3390	103	22	79	12.3	4.6	1.15	1.03	100	100	
62	215	39	61	0	7	41	3235	108	43	83	4.8	0.9	1.24	1.04	109	20	
62	216	0	100	0	2	39	3040	108									
62	219	33	67	12	27	64	2355	109	52	84	10.0	3.8	1.05	0.96	107	100	
62	220	43	57	20	33	61	3055	106	37	79	11.2	6.3	0.84	0.88	101	75	W.O.K.
35	221	39	61	15	30	66	3100	104	50	80	12.0	7.0	0.81	0.90	104	10	W.O.K.
35	222	48	52	26	43	71		107	47	84	10.2	5.3	0.93	1.01	98	0	W.O.K.
21	223	63	37	62	68	75			47	73	10.4	2.3	1.02	1.03	107	20	W.O.K.
21	224	94	6	0	0	14			21	60	12.2	2.0	0.84	0.95	101	15	W.N.G.
51	225	54	46	22	27	49	2525	97	45	73	17.0	7.8	1.14	1.08	101	75	W.O.K.
51	226	61	39	19	28	50	2530	98	35	72	14.7	5.9	1.03	0.99	101	50	W.O.K.
51	227	85	15	0	0	19			62	90	3.7	1.0	1.18	1.14	107	0	
51	228	0	100	0	0	6	3475	98									
51	229	93	7						60	90	2.7	0.5	1.20	1.21	106	0	
51	230	44	56	33	39	67	3056	110	54	90	5.5	2.7	1.20	1.13	106	25	
45	231	43	57	22	39	68	2595	110	44	79	9.0	3.7	1.12	1.08	107	0	W.O.K.
45	232	0	100	0	0	35	3150	110									
45	233	87	13						36	65	15.7	2.2	0.99	0.98	110	0	
28	234	59	41	5	21	45		101	26	68	15.0	3.7	0.96	1.11	105	0	
35	235	8	92	30	46	81	3185	99									
7	236	39	61	0	23	64	2985	104	56	92	2.6	1.0	1.13	1.09	104	100	

7	237	31	69	8	21	68	3010	106	64	94	2.0	0.9	1.21	1.07	104	100	
45	240	48	52	22	30	64	2960	110	70	89	6.3	3.5	1.01	1.01	108	100	
45	241	43	57	23	37	71	3210	108	49	86	4.5	1.4	1.25	1.08	109	0	
51	242	59	41	16	30	68	3360	111	53	84	5.6	2.0	1.27	1.12	109	0	
51	243	35	65	42	51	73	3525	109	57	87	5.1	2.6	1.37	1.20	109	0	
51	244	71	29	26	35	51	3500	104	50	84	6.9	3.2	1.23	1.21	106	0	W.O.K.
51	246	73	27	19	19	27	3485	100	64	87	6.1	3.7	1.23	1.09	106	0	
21	247	77	23	0	12	18	3920	98	59	84	8.0	4.7	1.05	1.02	109	0	W.O.K.
21	248	64	36	12	16	29	3920	99	72	92	3.6	1.9	1.25	1.07	108	0	
18	249	85	15	0	0	2		94	69	91	5.8	4.6	0.97	0.96	97	0	W.O.K.
18	250	83	17	0	0	6		91	57	82	7.4	4.0	1.00	1.04	98	0	W.O.K
18	251	79	21	0	0	8	3650	96	59	89	4.3	2.4	1.38	1.13	103	0	
18	252	55	45	18	24	42	3840	101	68	91	3.4	1.6	1.34	1.26	106	0	
36	253	93	7						46	72	9.9	2.6	1.22	0.98	110	100	
35	254	74	26	0	0	12	2980	102	69	89	3.7	0.7	1.14	1.03	107	50	
18	259	28	72	47	57	76	3225	109	62	91	5.0	3.4	1.02	1.01	101	0	W.O.K.
18	260	57	43	32	39	62	3250	106	56	91	2.8	1.6	1.00	0.97	103	75	
18	261	46	54	8	14	38	3515	105	63	92	3.8	1.8	1.07	1.03	106	150	
18	262	35	65	13	34	55	3485	110	72	87	5.0	1.7	1.07	1.03	109	75	
18	266	32	68	21	41	67	2730	106	56	81	8.2	4.2	1.19	1.08	109	25	W.O.K.
44	267	68	32	0	0	4	3940	101	68	95	0.9	0.3	1.20	1.05	108	0	
1	268	100	0						18	83	4.0	2.1	1.02	0.93	92	25	
3	269	100	0						6	72	4.9	1.8	.81	.86	91	50	
47	270	45	55	5	15	50	3270	102	68	93	1.8	0.4	1.24	1.13	104	0	
47	271	3	97	11	21	69	3360	93									
47	272	5	95	7	22	70	3850	94									
8	273	34	66	8	21	62	3460	108	53	85	4.3	1.2	1.22	1.09	110	25	
8	274	29	71	36	72	93	3180	107	39	87	6.4	3.6	1.06	1.03	99	15	W.N.G.
8	275	2	98	25	37	71	3290	105	73	86	9.5	6.0				1500	
8	276	11	89	35	51	82	3410	109	49	78	13.0	9.1	.68	0.83	108	200	W.O.K.[6]
8	277	65	35	0	0	27	3320	104	63	90	3.1	0.9	1.07	1.02	105	100	
30	281	48	52	10	19	53	3030	105	41	75	11.0	5.3	.90	.92	103	200	W.N.G.
30	282	59	41	20	32	64	3085	107	43	75	7.2	2.6	.96	.99	102	100	
30	283	78	22	17	17	41	3440	102	40	79	6.9	2.4	.97	.96	101	100	

[6]Dirty gravel.

TABLE NO. 2—MATERIAL TESTED FOR USE AS CONCRETE

Co. Ref. No.	Serial No.	GRAVEL: Percent Sand	GRAVEL: Percent Gravel	GRAVEL: Percent Retained on Screen 3 in.	2 in.	1 in.	GRAVEL: Compress. Strength 1:2:3 Concrete lbs. per sq. inch	GRAVEL: Wt. per cu. foot	SAND: Percent Retained on Sieve 20	50	Passing Sieve 100	Silt	SAND: Tensile Test 1:3 Mortar Ratio to Standard Sand 7 days	28 days	Weight per cubic foot	Organic Content parts per million	Remarks
30	284	78	22	11	25	44	2580	103	42	79	6.6	2.7	1.08	1.03	100	100	
30	285	89	11	0	20	55			15	61	12.9	5.8	.71	.77	95	200	W.N.G.
30	286	42	58	5	14	52	2780	105	52	75	10.6	4.1	.98	.98	106	125	W.O.K.
30	287	53	47	0	8	44	3190	103	56	86	6.8	2.2	1.18	1.08	103	75	
30	288	76	24	24	41	66			32	83	4.5	1.2	1.00	1.01	98	75	
28	289	36	64	29	54	74			35	72	15.7	9.4	.95	.93		0	
21	292	61	39	4	10	16	3280	94	54	90	1.6	0.4	1.08	1.16	104	10	
21	293	57	43	0	4	22	2810	97	58	87	4.1	1.4	1.19	1.11	105	50	
21	294	85	15	0	0	29			49	83	6.2	2.9	1.27	1.23	100	10	
21	295	95	5	0	0	0			52	76	11.2	2.7	1.04	1.01	109	100	
35	297	30	70	31	48	76		108	57	83	10.4	6.6	0.99	1.08	106	0	W.O.K.
35	298	30	70	28	51	82		111	50	74	13.7	9.6	1.02	1.11	107	0	W.O.K.[8]
35	299	33	67	9	26	71	2625	109	40	87	3.0	1.2	0.98	1.03	100	25	
35	300	40	60	6	22	61	2725	110	65	90	3.2	1.4	1.02	1.09	105	100	
28	301	57	43	10	19	49		101	34	75	11.5	5.3	1.30	1.26	105	0	W.O.K.
28	302	59	41	14	26	55	3670	101	27	69	13.4	6.2	1.20	1.18	104	0	W.O.K.
62	303	28	72	0	0	36	2960	107	54	91	1.7	0.3	1.03	1.07	105	0	
62	304	38	62	2	15	61	2550	109	57	90	2.2	0.8	1.01	1.07	105	0	
35	305	30	70	33	45	73	2445	109	60	93	3.4	1.7	1.16	1.12	100	0	
35	306	34	66	7	33	68	2210	109	43	84	6.5	3.7	1.24	1.16		250	W.O.K.
35	307	32	68	8	37	67	2210	110	45	79	8.2	3.5	0.93	0.97		200	W.O.K.
44	308	76	24	0	10	23	3070	102	55	92	1.0	0.5	1.19	1.17	106	0	
44	309	44	56	7	30	62	2750	106	65	86	7.4	4.4	1.11	1.21	102	0	W.O.K.
38	311	61	39	2	9	42	3260	104	72	95	1.7	1.2	1.49	1.19	104	0	
38	312	0	100	1	16	71	2490	104									

[7]N. G. Soft Shale in gravel.

[8]N. G. Soft Shale in gravel.

38	313	1	99	10	30	80	2560	103								
38	314	52	48	0	6	43	3240	105	65	89	3.9	2.0	1.28	1.20	108	0	
21	315	98	2						42	83	5.7	2.4	1.12	1.11	95	100	
21	316	95	5						59	88	3.4	0.9	1.16	1.19	103	25	
21	317	89	11						44	77	9.7	3.4	1.03	1.20	98	200	W.O.K.
35	318	35	65	7	22	63			63	87	5.6	1.8				0	
60	319	0	100	0	0	96	3970	86									
60	320	0	100	0	16	82	3885	91									
60	321	0	100	0	4	84	4120	87									
35	326			0	0	52	3240	104	47	87	4.6	1.6	1.01	1.02	103	100	
35	334	29	71	36	49	74	2890	103	54	80	12.3	8.5			103		[9]
51	342	95	5	0	0	0			38	81	5.6	2.0	1.25	1.20	103	0	
22	343	36	64	14	31	66	3985	99	18	67	7.7	2.1	0.92	1.01	101	0	
22	344	74	26	32	56	81	3985		16	65	10.5	2.9	1.09	1.05	100	0	
35	345			0	0	59	3345	103	51	81	11.6	6.2			102	0	
35	346			0	0	61	2655	102	70	88	7.9	5.3			102	0	
35	347			0	0	59	3155	101	68	92	4.3	2.1	1.23	1.15	101	0	
35	348	100.0	0						41	84	5.9	2.6	1.08	0.93	105	0	
35	349	100.0	0						37	90	2.9	1.0	1.05	1.08	104	0	
50	350	68	32	0	15	33	3885	98	63	88	7.5	5.7	1.16	1.20	107	0	W.O.K.
50	351	57	43	8	22	55	3250	103	43	86	5.7	3.8	1.11	1.11	106	0	W.O.K.
35	354	93	7						55	89	4.3	1.5	1.35	1.24	101	0	
45	356	52	48	0	0	11	3420	96	65	82	11.0	8.1	1.43	1.28	108	0	W.O.K.
45	357	47	53	0	3	14	3390	93	70	84	10.2	7.5	1.55	1.37	103	0	W.O.K.
45	359	5	95	0	0	69	3530										
45	360	63	37	0	9	42	3530	103	55	88	7.4	5.2	1.21	1.18	106	0	W.O.K.
45	361	55	45	0	24	69	3460	105	37	81	4.7	2.3	1.05	0.98	104	0	
45	362	18	82	0	10	41	3780	105									[10]
45	363	42	58	0	14	71	2990	105	44	85	4.5	1.0	1.31	1.19	109	0	
45	364	67	33	0	7	42	3530	105	49	85	3.2	0.8	1.37	1.22	109	0	
35	372	35	65	15	31	61	3205	107	57	87	6.1	2.5	1.41	1.35	110	0	
7	377	51	49	0	7	56		107	51	87	3.5	1.0	1.35	1.16	105	25	
7	378	32	68	0	8	43	3413	107	72	91	4.5	2.6	1.29	1.16	102	100	
7	379	41	59	0	12	53	3746	107	58	87	3.4	1.4	1.37	1.25	105	25	
25	387	52	48	0	8	43	3380	98	41	68	19.3	14.7			106	100	W.O.K.

[9]Calcium carbonate coating on pebbles. [10]Calcium carbonate on pebbles.

TABLE NO. 2—MATERIAL TESTED FOR USE AS CONCRETE

Co. Ref. No.	Serial No.	GRAVEL Percent		GRAVEL Percent Retained on Screen			GRAVEL Compress. Strength 1:2:3 Concrete lbs. per sq. inch	GRAVEL Wt. per cu. foot	SAND Percent Retained on Sieve 20	SAND Percent Retained on Sieve 50	SAND Percent Passing Sieve 100	SAND Silt	SAND Tensile Test 1:3 Mortar Ratio to Standard Sand 7 days	SAND Tensile Test 1:3 Mortar Ratio to Standard Sand 28 days	SAND Weight per cubic foot	SAND Organic Content parts per million	Remarks
		Sand	Gravel	3 in.	2 in.	1 in.											
25	388	45	55	0	11	48	3060	95	48	71	21.4	17.4			110	100	W.O.K.
25	389	47	53	12	31	62	3840	97	49	76	12.3	7.7	1.24	1.16	109	0	W.O.K.
52	390	23	77	20	46	74	3650	108	30	72	14.8	8.8	1.13	1.08	112	100	W.O.K.
41	393	33	67	7	23	59	3300	111	43	76	13.6	6.8	1.12	1.11	112	0	W.O.K.
41	394	48	52	0	0	45	3390	109	41	76	12.7	8.2	0.97	1.00	111	0	W.O.K.
41	395	29	71	8	21	66	3235	111	49	84	5.2	2.3	1.40	1.37	110	0	
52	396	24	76	19	38	78	3570	105	26	66	18.2	10.9			107	75	W.O.K.
52	397	19	81	44	54	80	3540	105	35	56	31.6	20.1				50	W.O.K.
35	404	45	55	0	11	49	2850	107	61	84	6.2	2.2	1.36	1.28		0	[11]
59	408	35	65	32	46	68	3850	109	56	83	9.4	6.1	1.12	0.91	111	200	W.O.K.
59	409	39	61	33	48	71	3460	108	59	87	8.2	5.9	1.11	1.03	101	0	W.O.K.
59	410	24	76	53	65	80	3850		43	77	14.7	11.2	0.88	0.83	106	0	W.O.K.
59	411	27	73	46	65	83	4150		48	69	24.2	21.2	0.74	0.67	101	0	W.O.K.[12]
59	412	42	58	29	44	70	3340	109	35	73	16.7	12.6	0.85	0.83	102	0	W.O.K.
25	413	45	55	0	16	41	3960	98	46	64	26.0	18.8	1.00	1.15	113	0	W.O.K.[13]
25	414	30	70	36	51	70	4115	110	54	77	18.1	15.9	1.04	1.08	105	0	W.O.K.
35	415			0	4	62	3420	105	49	84	4.9	1.8	1.02	0.97	107	100	
35	417	43	57	5	13	56	3370	112	58	91	3.7	1.6	1.19	1.12	104	0	
19	419	24	76	42	59	85	3870	109	16	77	7.7	4.2	1.19	1.11	102	0	W.O.K.
19	420	24	76	20	47	84	3920	104	16	69	16.0	9.9	1.05	1.10	104	0	W.N.G.
19	421	32	68	26	47	83	4180	108	26	78	12.9	8.1	1.15	1.09	105	75	W.O.K.
19	424	32	68	13	35	64	4170	108	46	86	6.2	2.4	1.36	1.35	109	0	
19	426	19	81	7	23	74	3525	104	44	73	9.4	4.2	1.21	1.10	110	0	W.O.K.
23	427	46	54	5	9	32	4950	97	53	70	21.1	14.7	1.21	1.15	112	0	W.O.K.
23	428	39	61	0	9	48	4200	100	50	70	21.6	15.6	1.21	1.15	111	0	W.O.K.

[11]Contains clay streaks. [13]Some soft sandstone in sand and gravel. [12]Some soft shale in gravel.

23	432	34	66	4	19	48	3660	112	49	86	7.1	4.1	1.51	1.27	111	0	W.O.K.
23	435	37	63	35	50	73	3490	107	18	52	26.3	18.4			105	0	W.N.G.
23	436	36	64	9	28	66	3110	115	34	82	7.0	3.3	1.48	1.23	110	0	W.O.K.
23	437	25	75	10	27	70	3340	111	26	66	16.9	12.3	1.04	0.99	105	0	W.O.K.
23	440	36	64	0	16	52	3820	105	40	87	4.5	1.9	1.26	1.15	105	0	
23	441	41	59	8	23	62	2750	97	25	69	22.0	19.7	1.08	1.06	101	0	W.N.G.[14]
39	442	31	69	17	34	69	3635	107	31	62	23.3	13.6	0.99	1.00	109	75	W.O.K.
39	443	27	73	12	31	72	3220	106	26	50	25.0	11.0	1.01	1.04	107	75	W.O.K.
39	445	58	42	6	26	60	3555	98	33	80	6.4	2.8	1.23	1.21	103	0	
39	446	38	62	14	32	70	3380	105	21	69	11.5	5.0	0.99	1.05	104	0	W.O.K.
39	451	23	77	8	20	64	3200	104	34	61	22.6	16.2	1.11	1.06	105	125	W.O.K.[15]
35	265	0	100	0	3	50	2980	102									
39	454	25	75	18	38	74	2960	111	27	62	16.4	6.8	1.11	1.08	109	75	W.O.K.
29	455	95	5						21	76	6.4	2.6	0.91	0.94	99	0	
39	456	2	98	0	0	52	3910	103									
39	459	33	67	12	21	52	3145	110	33	82	4.4	1.9	1.11	1.05	107	50	
26	463	46	54	0	0	24	3800	102	24	79	5.4	1.8	0.94	0.87	96	150	
42	464	24	76	15	28	66	3835	102	54	80	10.0	7.1	1.30	1.24	107	0	W.O.K.
34	466	31	69	12	26	61	3870	105	51	83	8.6	5.8	1.18	1.10	105	0	W.O.K.
34	467	30	70	8	26	72	3740	110	25	63	17.6	11.8	1.19	1.26	108	0	W.O.K.
34	468	14	86	0	3	42	4095	93	61	72	21.3	15.9	1.48	1.47			W.O.K.
15	477	21	79	19	39	79	2905	108	27	52	21.1	9.1			107	25	W.O.K.
15	478	30	70			55	3690	108	23	74	9.4	5.2	1.13	1.00	105	50	W.O.K.
15	480	33	67	0	10	57	3670	111	27	75	8.9	4.4	1.12	1.08	106	25	W.O.K.
15	481	22	78	3	11	53	3215	109	33	66	21.3	13.4			110	200	W.O.K.
15	482	36	64	5	16	46	3865	105	42	73	11.2	6.0	1.44	1.20	111	0	W.O.K.
15	483	27	73	5	17	60	3700	104	27	57	20.6	11.7			107	15	W.O.K.
26	485	26	74	0	18	63	3770	111	59	87	5.3	2.7	1.35	1.09	110	125	
43	489	25	75	9	21	61	3485	106	40	60	19.7	10.3			112	15	W.O.K.
43	490	33	67	4	10	45	3520	103	35	78	7.7	3.4	1.02	1.22	106	15	W.O.K.
43	491	27	73	17	32	65	3545	106	56	86	6.4	3.2	1.27	1.35	109	15	W.O.K.
46	492	26	74	19	37	67	4205	103	36	68	15.9	8.6	0.98	0.94	108	150	W O.K.
46	493	33	67	9	27	58	4040	106	56	85	6.1	2.8	1.59	1.35	114	0	
42	494	34	66	0	13	60	3320	100	35	69	16.0	9.9	1.14	0.98	111	225	W.O.K.
42	496	29	71	29	48	69	3820	106	46	75	13.3	9.5	1.04	0.88	107	250	W.O.K.

[14]Approx. 5% soft shale in sand and gravel. N. G. [15]Some soft oil shale in gravel.

TABLE NO. 2—MATERIAL TESTED FOR USE AS CONCRETE

Co. Ref. No.	Serial No.	GRAVEL Percent Sand	GRAVEL Percent Gravel	GRAVEL Percent Retained on Screen 3 in.	2 in.	1 in.	GRAVEL Compress. Strength 1:2:3 Concrete lbs. per sq. inch	GRAVEL Wt. per cu. foot	SAND Percent Retained on Sieve 20	50	SAND Percent Passing Sieve 100	SAND Percent Silt	SAND Tensile Test 1:3 Mortar Ratio to Standard Sand 7 days	28 days	SAND Weight per cubic foot	SAND Organic Content parts per million	Remarks
34	497	32	68	12	32	65	3940	112	55	94	2.4	1.1	1.31	1.22	105	25	
34	501	32	68	13	87	52	4055	114	73	90	4.2	1.7	1.37	1.20	114	125	
4	502	18	82	40	64	84	3600	107	35	64	18.8	10.9	1.06	0.95	110	200	W.O.K.
4	504	19	81	18	43	78	3645	106	25	67	12.9	5.2	0.93	0.97	102	100	W.O.K.
4	505	9	91	16	33	79	3570	105	11	35	30.2	11.2			94	200	W.N.G.
4	506	25	75	25	36	72	3470	106	51	79	11.5	7.7	1.07	1.04	106	50	W.O.K.
53	509	24	76	23	38	72	3520	106	51	83	6.3	3.3	1.07	1.03	103	75	W.O.K.
53	510	43	57	0	0	38	3840	101	58	87	5.3	2.9	1.11	0.99	107	200	
55	512	39	61	4	17	61	3510	98	40	87	4.4	2.3	0.87	0.82	101	100	
55	513	80	20	0	0	86		94	35	86	2.4	0.9	0.89	0.89	97	100	

ABBREVIATIONS FOR TABLE III

W. O. K......**Washed sand O. K.**
W. N. G.....**Washed sand not good**
Ref. ..... **Reference**
Str. ..... **Strength**
Stan. ..... **Standard**
Approx. ..... **Approximately**

TABLE NO. 3—MATERIALS TESTED FOR USE AS SURFACING

Co. Ref. No.	Serial No.	Percent Retained 1½" Screen	Percent Retained 10 Mesh Sieve	Percent Passing 100 Mesh	Cem't'g Val. Material Passing ¼"	Weight Per Cubic Foot Ret. ¼"	Weight Per Cubic Foot Pass. ¼"	Weight Per Cubic Foot Pit Run	Remarks
4	11	42	80	1.8	1000				
4	12	20	80	3.8	1085				
4	14	16	68	10.2	2040				
43	70	14	86	5.2	500				
43	71	8	73	6.6	500				
43	72	30	85	3.7	500				
43	73	14	78	7.1	500				
26	87	0	66	4.5	67				
55	98	0	11	19.8					Good material
55	99	0	1	56.3					Poor material
55	100	0	1	35.9					Poor material
55	117	0	12	22.	120				Good material
55	101	0	0	70.4					Poor material
55	118	0	1	80.	99				Poor material
55	102	0	10	21.0					Good material
55	119	0	1	65.	121				Poor material
1	124	6	48	4.2	54	107	107		
1	129	39	74	5.9	365	106	107		
1	130	34	78	3.8	384	106	104		
3	159	42	75	3.5	210	101	105		
62	165	6	58	0.8	36	102	109		
62	166	0	33	2.6	46		109		
62	167	0	41	3.1	38		107		
62	168	0	34	5.6	105		97	98	
62	169	0	33	19.7	431	103	102		
62	172	0	55	1.5	42	98	110		
62	173	0	41	6.0	88	96	103		
62	174	0	54	4.6	118	99	108		
62	175	0	40	3.2	42	96	106		
62	176	0	44	3.1	34	97	105		
50	181	0	47	2.4	64	100	111		
50	182	23	68	7.9	389	92	108		
50	183	27	73	1.8	81	107	108		
50	184	32	73	11.4	515	94	102		
50	185	41	77	6.8	410	94	107		
50	186	10	47	4.4	61	101	111		
50	188	40	69	4.2	231	103	110		
35	190	11	45	15.2	500	91	99		
35	191	10	46	12.2	500	97	98		
35	221	33	70	4.7	357	104	104		
30	239	27	73	8.1	1000	104	94		
51	242	22	57	3.3	52	111	109		
51	243	41	76	1.8	125	109	109		
51	244	12	46	4.9	148	104	106		
51	246	7	52	4.5	59	100	106		
21	247	3	48	6.1	124	98	109		
21	248	8	62	2.2	57	99	108	115	
18	249	0	48	5.0	202	94	97	101	
18	250	0	44	6.1	73	91	98	102	

TABLE NO. 3—MATERIALS TESTED FOR USE AS SURFACING

Co. Ref. No.	Serial No.	Percent Retained 1½" Screen	Percent Retained 10 Mesh Sieve	Percent Passing 100 Mesh	Cem't'g Val. Material Passing ¼"	Weight Per Cubic Foot Ret. ¼"	Weight Per Cubic Foot Pass. ¼"	Weight Per Cubic Foot Pit Run	Remarks
18	251	1	45	3.4	54	96	103	108	
18	252	15	67	1.9	22	101	106	116	
35	297	47	80	3.0	190	108	106		
35	298	48	78	4.0	310	111	107		
44	308	4	45	0.8	43	102	106		
44	309	26	72	3.2	388	106	102		
44	310	24	72	7.1	500	104	100		
38	314	11	69	2.0	88	105	108		
21	329	0	36	1.1	50			101	
20	330	0	35	21.1	670			93	
21	331	0	21	20.5	600			87	
21	332	0	37	8.4	396			93	
21	333	0	33	14.4	512			90	
35	334	44	78	3.5	215	103	103		Calicum carbonate
22	335	39	77	4.1	325	105	107		2.4% on pebbles
22	336	17	49	16.5	381	98	104		
22	337	19	84	9.6	200	84	82		
22	338	43	67	4.4	237		106	113	
22	339	0	21	26.0	3300		99	105	
22	343	32	67	2.9	140	99	101		
22	344	18	30	7.8	168		100		
50	350	8	56	5.0	190	98	107	115	
50	351	17	54	3.2	209	103	106	119	
6	352	14	59	5.2	170	101	108	119	
6	353	10	59	6.0	200	98	107	119	
45	355	11	74	14.3	192	89	100	106	
45	356	1	70	5.7	97	96	108	114	
45	357	3	74	4.7	111	93	103	106	
45	358	29	69	19.4	232	67	83	91	
40	374	7	100	0.0	460	75		75	
40	375	2	100	0.0	425	75		75	
45	376	15	57	33.1	297	83	87	102	
35	380	0	63	11.4	570	97	108	115	
35	381	1	66	6.9	300	97	110	116	
25	387	12	59	10.1	340	98	106	116	
25	388	14	67	9.7	246	95	110	118	
25	389	25	63	5.8	244	97	109	121	
52	390	48	80	3.4	229	108	112	129	
52	391	60	86	5.8	244	80	85	96	
41	392	21	72	10.2	212	88	110	115	
41	393	27	75	4.5	140	111	112	128	
41	394	14	61	6.1	282	109	111	125	
52	396	45	80	4.4	183	105	107	125	
52	397	53	86	5.9	162	105		126	
52	398	28	78	12.6	510	69	90	90	
52	399	53	100	0.0	510	71			
59	408	36	77	3.3	180	109	111	126	
59	409	36	70	3.2	169	108	101	117	

TABLE NO. 3—MATERIALS TESTED FOR USE AS SURFACING

Co. Ref. No.	Serial No.	Percent Retained 1½" Screen	Percent Passing 10 Mesh Sieve	Percent Passing 100 Mesh	Cem't'g Val. Material Passing ¼"	Weight Per Cubic Foot Ret. ¼"	Weight Per Cubic Foot Pass. ¼"	Weight Per Cubic Foot Pit Run	Remarks
59	410	54	80	3.6	231		106	124	
59	411	54	79	6.6	368		101	117	Some soft shale in gravel
59	412	33	64	6.9	216	109	102	118	
25	413	15	67	11.6	250	98	113	120	Some soft sandstone in sand and gravel
19	424	34	74	2.0	86	108	109	124	
19	418	38	64	27.7	153	96	96	113	
19	419	56	78	1.8	63	109	102	126	
19	420	54	78	3.8	161	104	104	123	
19	421	45	70	4.1	127	108	105	124	
19	422	1	32	37.7	133	72	94	97	Vol. Rock
25	414	41	79	5.5	263	110	105	121	
19	425	12	67	19.1	92	93	100	112	
19	426	43	86	1.8	94	104	110	128	
23	427	9	69	9.7	107	97	112	122	
23	428	15	73	8.3	107	100	111	121	
23	431	13	60	6.5	226	95	105	114	
23	432	22	76	2.4	80	112	111	125	
23	433	1	60	20.9	240	94	104	113	
23	434	28	69	19.5	545	97	98	113	
23	435	38	67	9.7	246	107	105	125	
23	436	32	70	1.5	96	115	110	133	
23	437	38	80	4.2	188	111	105	125	
23	440	19	73	1.6	152	105	105	121	
23	441	26	64	8.9	229	97	101	118	Approx. 5% soft shale in sand and gravel
39	442	36	75	7.2	168	107	109	127	
39	443	40	78	6.6	147	106	107	131	
39	444	2	59	16.4	750	99	97	111	
39	445	18	50	3.7	177	98	103	115	
39	446	33	68	4.3	118	105	104	123	
39	451	31	82	5.2	242	104	105	125	Some soft oil shale and gravel
39	452	50	80	6.9	107	107	102	125	
39	453	18	87	4.3	122	99	103	107	
39	454	44	80	4.1	138	111	109	132	
39	455	0	15	6.1	142		99		
39	456	1	100	0.0		103		103	
39	458	47	72	7.7	246	109	101	125	Soft shale in gravel
39	459	25	75	1.5	123	110	107	129	
39	460	32	73	11.8	226	107	107	126	
42	461	52	85	8.2	255	101	100	115	
34	462	37	72	12.5	1000	93	89	115	
26	463	6	61	2.5	257	102	96	115	
42	464	38	85	2.4	173	102	107	121	
34	465	44	79	7.7	490	92	95	110	
34	466	29	78	2.6	175	105	105	122	
34	467	36	74	5.2	154	110	108	131	
34	468	12	92	2.9		93		104	
26	469	3	61	12.4	280	87	103	108	

TABLE NO. 3—MATERIALS TESTED FOR USE AS SURFACING

Co. Ref. No.	Serial No.	Percent Retained 1½" Screen	Percent Retained 10 Mesh Sieve	Percent Passing 100 Mesh	Cem't'g Val. Material Passing ¼"	Weight Per Cubic Foot Ret. ¼"	Weight Per Cubic Foot Pass. ¼"	Weight Per Cubic Foot Pit Run	Remarks
15	477	48	83	4.3	311	108	107	135	
15	478	18	74	2.9	136	108	105	135	
15	479	17	64	5.4	262	103	115	128	
15	480	22	73	3.0	104	111	106	132	
15	481	21	83	4.7	231	109	110	131	
15	482	19	73	4.0	158	105	111	130	
15	483	28	78	5.6	288	104	107	128	
26	484	0	66	5.6	259	100	108	116	
26	485	28	82	1.4	167	111	110	128	
26	486	10	53	11.5	500	86	102	107	
43	488	38	81	5.5	266	106	106	124	
43	489	31	82	4.9	256	106	112	125	
43	490	15	73	2.5	230	103	106	124	
43	491	36	82	1.6	267	106	109	124	
46	492	38	80	4.2	206	103	108	125	
46	493	28	77	2.0	162	106	114	127	
42	494	26	73	5.4	172	100	111	123	
42	495	54	81	12.5	1100	100	89	114	
42	496	42	79	3.8	147	106	107	124	
34	497	32	76	0.7	68	112	105	126	
34	498	29	76	11.8	304	98	109	118	
34	499	14	71	20.4	162	97	98	115	
34	500	46	79	3.2	135	111	106	133	
34	501	25	84	1.3	95	114	114	127	
4	502	61	87	3.4	237	107	110	129	
4	504	51	84	2.5	333	106	102	125	
4	505	54	92	2.7	279	105	94	120	
4	506	42	82	2.9	343	106	106	126	
53	507	17	76	18.7	910	76	96	100	
53	508	2	57	11.4	217	83	105	105	
53	509	41	83	1.6	333	106	103	127	
53	510	11	72	2.2	267	101	107	121	
55	511	18	62	7.0	410	95	101	111	
55	512	24	70	1.7	212	98	101	119	
55	513	1	33	1.9	182	94	97	105	
55	515	10	70	13.5	557	94	101	117	

ABBREVIATIONS FOR TABLE IV

W. O. K......Washed sand O. K.
W. N. G......Washed sand not good
Ref. ..... Reference
Str. ..... Strength
Stan. ..... Standard
Approx. ..... Approximately

TABLE NO. 4—ROCK TESTS

Co. Ref. No.	Serial No.	Kind of Rock	Specific Gravity	Percent Absorption	Percent Wear	French Coefficient of Wear	Hardness Coefficient	Toughness Coefficient	Cementing Value	Comp. Str. 1:2:3 Concrete lbs. per sq. in.
28	2	Basalt	2.76	0.9	4.21	9.50			2580	
35	4	Schist	2.84	0.03	8.25	4.85	15.1	4.0	65	
4	6	Rhyolite	2.40	1.9	5.24	7.64	16.2	10.0	1045	
4	7	Quartzite	2.56	2.44	3.67	10.90	17.9	4.0	34	
4	8	Sandstone	2.47	2.62	3.79	10.55	15.7	6.0	334	
4	9	Sandstone	2.55	2.12	3.69	10.84	17.6	7.0	406	
4	10	Sandstone	2.39	3.83	4.55	8.79	11.2	7.0	2000	
4	13	Shale							950	
34	15	Rock	2.64	0.8	3.25	12.31			1160[1]	
	16	Shale	2.45						4800	
21	17	Sandstone	2.34	2.64	6.93	5.77	10.1	5.0	52	
21	19	Limestone	2.74	0.0	5.00	8.00	12.4		75	
21	20	Limestone	2.72	0.0	3.65	10.96	14.4	6.0	47	
21	21	Limestone	2.69	0.2	4.62	8.66	18.0	4.0	29	
21	22	Limestone	2.56	2.5	3.65	10.96	14.7	8.5	33	
18	23	Limestone	2.92	0.3	3.21	12.46	17.4	22.	31	
60	25	Trap	2.58	1.0	2.87	13.94			450	
36	29	Limestone	2.47	3.5	5.34	7.49	12.9	8.5	47	
36	30	Basalt	2.87	0.5	2.73	14.65	17.4	13.0	13	
51	39	Limestone	2.52	2.8	4.42	9.05	13.2	10.0	196	
28	40	Limestone	2.58	2.1	4.01	9.98	15.9	9.5	37	
20	42	Coal Shale	1.87	12.0	7.33	5.46			71	
7	43	Sandstone	2.46	1.4	2.84	14.08	18.7	13.0	47	
16	44	Limestone	2.24	7.1	4.95	8.08	7.8	5.5	63	
7	46	Sandstone					16.6	9.0		
7	47	Sandstone	2.44	1.4	3.60	11.11				
7	48	Sandstone	2.41	2.0	4.64	8.62				
7	49	Sandstone	2.42	1.5	4.58	8.74			33	
7	50	Sandstone			5.05	7.92				
7	51	Sandstone			6.09	6.57				
7	52	Sandstone			15.71	2.55				
7	53	Sandstone			7.84	5.10				
23	64	Granite	2.73	0.3	4.12	9.71			52	
23	65	Quartzite	2.65	0.9	4.54	8.81			30	
23	66	Limestone	2.69	0.2	5.65	7.08	13.4	3.5	38	
23	67	Limestone	2.69	0.1	4.86	8.23	14.0	6.5	41	
35	74	Sandstone	2.43	1.7	3.93	10.18	16.7	9.0		3900
35	75	Sandstone	2.40	2.1	5.11	7.83	14.1			
35	76	Sandstone	2.37	1.9	3.37	11.87	15.9	8.0		
35	77	Sandstone	2.40	1.9	3.92	10.20	15.9	8.0		
35	78	Sandstone	2.48	1.2	3.65	10.96	17.7	9.5		
35	79	Sandstone	2.46	1.3	3.06	13.07				
35	80	Sandstone	2.44	1.9	2.96	13.51				
35	81	Sandstone	2.44	1.4	3.72	10.75	17.3	7.0		
7	83	Basalt	2.82	0.1	2.21	18.10				
35	84	Sandstone	2.38	3.2	6.39	6.26	14.7	6.0		
7	89	Sandstone	2.50	1.0	3.70	10.81			68	

[1]Crushed Boulders.

TABLE NO. 4—ROCK TESTS

Co. Ref. No.	Serial No.	Kind of Rock	Specific Gravity	Percent Absorption	Percent Wear	French Coefficient of Wear	Hardness Coefficient	Toughness Coefficient	Cementing Value	Comp. Str. 1:2:3 Concrete lbs. per sq. in.
7	90	Sandstone	2.45	1.5	3.71	10.78				
7	91	Sandstone	2.44	2.0	3.25	12.31	17.2	8.0		
7	92	Sandstone	2.44	2.3	3.61	11.08				
51	94	Limestone	2.58	2.3	3.69	10.84	15.1	10.5	154	
7	95	Limestone	2.65	0.5	5.88	6.80	13.9	3.0		
7	96	Limestone	2.75	0.1	5.26	7.61	14.5	4.5		
44	115	Limestone	2.78	0.3	4.22	9.48	12.1	3.0		
30	156	Sandstone	2.34	3.0	3.38	11.83	13.2	6.0		
51	164	Limestone	2.54	2.6	3.75	10.67	13.9	9.5		3660
50	187	Shale	2.13	9.8	9.05	4.42			188	
35	189	Limestone	2.65	0.1	4.50	8.89	14.4	4.5		
42	218	Limestone	2.61	0.8	3.99	10.02	14.1	7.5	82	
7	238	Burnt Shale	2.02	11.1	16.52	2.42			35	
21	256	Stone	2.69	1.3	4.13	9.69	10.8	5.5	327	3510
30	257	Limestone	2.57	2.0	4.42	9.05	14.5	9.0	45	2850
30	258	Limestone	2.50	2.9	4.27	9.37	12.4	6.5	37	3810
18	263	Sandstone	2.28	4.2	29.91	1.34	8.6	2.5	25	
18	264A	Limestone	2.17	9.2	25.31	1.58	17.0	2.0		
47	271	Quartz and Schist	2.76	0.2	5.92	6.76				3360
47	272	Quartz and Schist	2.74	0.6	4.80	8.33				2850
22	279	Limestone	2.68	0.8	11.46	3.49	13.8	8.0	31	
7	280	Burnt Shale	2.05	6.8					6	
28	290	Basalt	2.72	1.4	3.97	10.08				
21	296	Limestone	2.52	3.1	5.93	6.74	14.3	7.0		
60	322	Trap	2.56	1.5	2.90	13.79	18.3	25		
30	324	Granite	2.73	0.5	3.53	11.33	17.5	8.0		4000
7	328	Quartzite	2.58	0.6	2.68	14.93				3070
22	340	Sandstone	2.17	1.6	30.2	1.32			5000[2]	
51	341	Limestone	2.52	2.8	3.39	11.80	14.0	8.0	60	4180
45	359	Limestone	2.33	6.5	5.53	7.23	4.3	5.0	95	
55	405	Rhyolite	2.37	1.8	6.23	6.42	16.7	5.7	52	
23	406	Limestone	2.68	0.1	4.45	8.98	13.6	4.5	26	3860
25	407	Dacite	2.35	2.5	5.04	7.94	14.0	7.0	94	4840
19	423	Volcanic Rock	2.16	3.1	7.79	5.13	18.3	10.0	103	4000
52	438	Shale	2.33	4.0	3.56	11.23	13.2	10.5	129[3]	
52	439	Shale	2.21	5.1	4.19	9.55	9.4	7.0	167[4]	
55	449	Granite	2.60	0.9	20.10	1.99	17.8	3.5	31[5]	
55	450	Rhyolite	2.06	4.8	6.98	5.73	16.4	8.5	32	
39	457	Sandstone	2.35	2.3	4.81	8.32	14.4	6.5	40	4465
26	470	Gneiss	2.67	0.5	4.37	9.15			52	
55	476	Basalt	2.68	0.6	2.72	14.70	18.9	17.5	12	4170
55	514	Basalt	2.64	0.6	3.07	13.02	18.7	22	32	4170

[2]Makes excellent road.
[3]Oil Shale
[4]Oil Shale.
[5]Disintegrated.

INTERPRETATION OF DATA

General.—In the interpretation of data in tables, it should be borne in mind that samples were taken after all stripping had been removed. In opening a pit, the tendency is to do an insufficient amount of stripping, thereby lowering the quality of the material produced. Information relative to average depth and amount of stripping and extent of pit is on file. Much other information relative to these deposits is also on file, such as complete mechanical analysis, specific gravity and voids of both gravel and sand, availability of railroads and highways and general remarks on conditions affecting operation of deposits. Copies of all the above information relative to any particular deposit may be had on request. All tests were made upon samples as received in the laboratory. These samples were carefully taken by experienced men in accordance with standard methods for sampling. Every care has been used to obtain samples representative of the deposits, but no guarantee can be made that any material plant operating in said deposit will produce material which will conform to the results given herein.

Detailed Interpretation—Table II.—The percent of sand and gravel in the deposit is shown. This information shows whether the pit will furnish sand and gravel in the relative amounts required by the mix which is to be used. If either sand or gravel must be wasted in order to obtain the desired mix, the extra cost of the work due to this waste may be computed or other sources sought from which to supply the deficient material. All material retained on a quarter-inch screen is classed as gravel, while that passing the same screen is sand.

The percentages of gravel retained on the three-inch, two-inch, and one-inch screens enables the amount of oversize and the consequent amount of gravel waste or crushing to be estimated.

The 28-day compressive strength of 1:2:3 concrete furnishes an indication of the strength which may be expected from the gravel under consideration when used in that mix with a good sand and Portland cement conforming to standard specifications. In the preparation of laboratory specimens, Platte River sand was used for all samples up to and including Serial No. 347, and Poudre River sand on all subsequent samples.

The weights per cubic foot of gravel and sand provide a means of estimating freight and hauling costs. The weights given are for room-dry material and have been determined according to standard methods. Sand, which is suitable for use in first-class concrete work, should conform to the following specifications: It shall consist of fragments of hard, tough, durable rock, graded from fine to coarse, with coarse particles predominating. Sand, when dry, shall pass a sieve having four (4) meshes per linear inch; not more than 75 percent shall pass

a sieve having twenty (20) meshes per linear inch; not more than 25 percent shall pass a sieve having fifty (50) meshes per linear inch; not more than 5 percent shall pass a sieve having one hundred (100) meshes per linear inch; it shall not contain vegetable or other deleterious matter nor more than three percent by weight of clay or loam, which may be removed by elutriation.

Sand shall be of such quality that mortar composed of one part Portland cement and three parts sand by weight, when made into briquettes or cylinders shall show a tensile or compressive strength at 7 and 28 days at least equal to the strength of similar specimens composed of one part of the same cement and three parts Standard Ottawa sand by weight. The percent of water used in making specimens of cement and sand shall be such as to produce a mortar of the same consistency as that of Ottawa-sand mortar of standard consistency.

Sands finer than the above recommended standard, when clean and structurally sound, may be used in concrete provided excess cement be used so as to produce concrete of equal strength to that developed when a first-class sand is used. This should only be considered when first-class sand is not available. In such cases, the mix should be worked out and thoroughly tested in the laboratory before its use is permitted. Extremely coarse sands will usually show high strength-ratios at both 7 and 28 days, but will produce a harsh concrete, which is hard to handle and invites the use of more water under field conditions, thereby weakening the concrete produced.

Sands containing in excess of three percent of silt by weight can usually be made suitable for use in first-class concrete by washing, provided they pass all other requirements of the sand specifications. The vigor of washing and the necessary amount of water can be estimated by comparing the mechanical analysis and silt content of the sand in question with the above recommended standard. Samples of washed sand should be tested frequently as the work progresses in order to make sure that the plant is functioning properly. Sufficient water should be used to actually wash the sand and not merely to wet it, as too small an amount of water will result in the silt forming a coating over the particles.

The use of good gravel and sand together with Portland cement, which has been tested and is known to conform to the Standards of The American Society for Testing Materials, should result in concrete of good quality, provided care is used in mixing and placing. Briefly, a few points to be watched in this connection are:

(1) Use the smallest amount of water with which it is possible to secure a concrete that can be satisfactorily placed. Any water in excess of this amount will lower the strength of the product.

(2) Use clean water, free from oil, acid, alkali or vegetable

matter. If the quality of the water is suspected, it should be tested to determine its suitability.

(3) Mix the ingredients thoroughly. The tendency always is to increase the amount of water and cut down on the time of mixing. Either of these will result in a decrease in strength, and a decrease in strength means that a part of the cement has been wasted. In other words, a concrete rich in cement, poorly mixed and containing excess water, may be weaker than one with less cement, but well mixed and containing a minimum of water for placing.

(4) Use care in placing. Place concrete immediately after mixing, in tight forms. Spade well, especially along forms. Be careful to secure a good bond between old and new work.

(5) The concrete should be kept moist after placing. The longer this is done the greater will be its strength. It should be protected against freezing in cold weather. The strength develops much more slowly in cold weather.

Sands containing organic matter in excess of 250 parts per million should not be used in first-class concrete unless the strength ratios are satisfactory; while those containing less than the above-mentioned maximum are usually safe, provided they are structurally sound and well graded. The field test, described later, for organic content in sands is a valuable method of determining whether the sand from a particular pit is at all times up to the standard set for that pit. Material should not, as a rule, be finally rejected for failure to pass this test, but should be held subject to results of other tests. If a pit has a low strength-ratio and a certain sample shows an increase in organic content, the material should be held for further tests.

Table III.—Sand and gravel for use as surfacing should pass a one-and-a-half-inch screen; not less than 70 percent should be retained on an eighth-inch screen. It should contain not less than five percent or more than 20 percent of binder, which may be removed by elutriation. This binder may consist of limestone dust, iron oxide, clay or other suitable material. The cementing value of the material passing a quarter-inch screen should not be less than 100. Material larger than the one-and-a-half-inch screen should not be used in the construction of a gravel surface but should be crushed to conform to the specifications given. The object at all times should be to obtain a surface of maximum density in order to prevent the penetration of moisture. Materials deficient in binder may be used by adding suitable binding material to them so as to produce a material conforming to the above specifications. This can often be procured along the roadside, but care should be used not to use too much roadside material and to mix it thoroughly with the gravel. If the roadside material does not pack readily in its natural state, because of excess sand, it should not be used as a binder.

A material containing binder in excess of 20 percent will pack quickly but will not wear, as there are not sufficient coarse particles to carry the traffic in wet weather.

Table IV.—Rocks listed in this table may be used for either concrete aggregate or Macadam surfacing, or both, depending on their properties. For use as concrete aggregate, a rock should have a French coefficient of wear of not less than eight. It should have a hardness coefficient of not less than 12, and a toughness coefficient of not less than five. For use in a Macadam surface, it should have a French Coefficient of not less than seven, and a cementing value of at least 50. The hardness and toughness coefficients are of value, when used together with the French coefficient of wear, in helping to show the reasons for the values obtained in the wear test.

A study of Table IV shows that the average value of the French coefficient of wear for the 58 deposits which were tested is 8.73. Of these, which include all kinds of rocks tested,

3 deposits had a French coefficient of wear greater than 14,
8 deposits had a French coefficient of wear greater than 12,
20 deposits had a French coefficient of wear greater than 10,
37 deposits had a French coefficient of wear greater than 8,
12 deposits had a French coefficient of wear less than 6,
6 deposits had a French coefficient of wear less than 4,
4 deposits had a French coefficient of wear less than 2.

The average value of the French coefficient of wear for all sandstone and quartzite deposits is 8.57; for limestone deposits, 8.43; for basalt deposits, 14.70; for granites, rhyolites and dacites, 7.48.

The French coefficient of wear furnishes a fairly satisfactory means of determining the suitability of a rock for use as aggregate for cement concrete or bituminous surfaces. In determining the suitability for Macadam, the French coefficient of wear should be considered in conjunction with the cementing value. A good instance of this is Serial No. 340, which has a coefficient of wear of only 1.3, but whose cementing value is over 5000. Due to its wonderful binding qualities, it makes an excellent road for medium-heavy traffic, even though the coefficient of wear is very low.

The average apparent specific gravity of basalt deposits is 2.71; granite, 2.68; rhyolite, 2.28; limestone, 2.57; sandstone, 2.41.

The need for tests on surfacing gravels is shown by the fact that of 180 samples tested only 34 passed all requirements of the specifications stated herein, and all of these contained more than five percent of material retained on a one-and-a-half-inch screen. Out of a total of 180 samples, 44 had less than five percent retained on the one-and-a-half-inch screen; 83 had less than 70 percent retained on the 10-mesh sieve; 75 had from five per-

cent to 20 percent, 89 had less than five percent, and 16 had more than 20 percent passing the 100-mesh sieve.

The average weight per cubic foot for all surfacing gravels was 100 pounds for material retained on, and 104.4 pounds for that passing, a quarter-inch screen.

From Table II, the average weight per cubic foot of sand for all samples tested is found to be 105.3, and of gravel, 104.

Out of 253 samples of sand tested for use as fine aggregate, 115 contained silt in excess of three percent by weight, leaving 138 samples which passed this requirement. Of 65 samples of sand from the Western slope, tested for use as fine aggregate, 53 contained more than three percent silt by weight and only 12 passed this requirement.

The average compression strength of 1:2:3 concrete made from 197 samples of gravel was 3223 pounds per square inch at the age of 28 days. The consistency of the concrete used was 1.0.

East of the front range and north of the general line of the Missouri Pacific R. R., we find deposits of both bank and river gravel. The bank gravel is usually a mixture of more or less angular rocks, sand and clay, which have been derived from the PreCambrian granite, which is pink in color, and the sandstones and limestones of the various sedimentary formations which are exposed along the edge of the front range. Of these, the granites compose by far the larger part. The pebbles and sand are often cemented together by means of a calcareous binder or the rocks are covered with a chalky substance. Clay streaks are also sometimes found in deposits of bank gravel.

These deposits are usually suitable for use as gravel surfacing, but are often not as suitable for concrete aggregate due to high silt content, the presence of pieces of the softer sandstones and the clay streaks above mentioned. Where the material is structurally sound and the deposit free from clay streaks, they may be used for concrete work, after washing to remove excess silt.

The river gravel which may be found along beds of streams issuing from the front range is very largely of granitic origin. These deposits contain sand and gravel in varying amounts. As a rule the farther from the mountains, the smaller the maximum size of gravel and the greater proportion of sand, which will be found. They are pink in color, and many of the pebbles are partially disintegrated.

While granite containing disintegrated pieces is not the best grade of material for use as coarse aggregate for concrete, it is in many places the only material locally available for this purpose. Concrete pavements, constructed of this gravel, some of which have been in use for over six years, are giving good service with low maintenance cost, and their present condition indicates that they have a long life still ahead of them. One

such example of pavement may be found in the City of Fort Collins, Colorado.

These river deposits often extend to considerable depths below the water level. With suitable machinery, it is possible to excavate from 10 to 20 feet below the surface of the water. Usually the deeper the excavation is carried, the greater will be the proportion of large boulders and the less the amount of sand. The large boulders are usually sound and when crushed, produce a coarse aggregate of better quality than the finer material.

The sands found in river gravels in this section are composed largely of quartz and felspar grains with some mica and hornblende. They are usually well graded, low in silt and relatively free from organic matter.

The principal road-building rocks in this section are those found in the mountain and foothill districts. They consist of granite, sandstone, limestone, and trap. Many quarries exist along the foothill region, and large amounts of the various types have been used for concrete and other structural purposes. The best known of these deposits are Lyons Sandstone, at Lyons, Golden Basalt from near Golden, and the mine dumps of the Victor-Cripple Creek region. There are other deposits from which a fine quality of rock might be produced at a reasonable cost, if the freight rates were lowered to permit it to be laid down on the job at a cost comparable to that of gravel. In this connection it would seem that the railroads are following a short-sighted policy, for here is a source of traffic which could be developed to a large extent if the rates were such as to encourage operation of quarries for production of road-building rock.

Some of the advantages of the use of quarry rock for concrete aggregate are uniformity in quality; the possibility of winter operation, thereby permitting winter hauling and storage of material on jobs ready for spring use; and the elimination of uncertainty as to cost of material, resulting in a lower allowance for contingencies and consequent lower cost.

South of the general line of the Missouri Pacific R. R. and east of the front range, we find general conditions different than those just described. The principal road-building rocks are limestone, trap and sandstone. Large deposits of these are found in this area. The Timpas and Greenhorn Limestones outcrop at many places in this section and are, in general, suitable for use both as surfacing and concrete material. These formations are thinly covered in many places and only require grading to produce a road surface suitable for light to medium traffic. The trap deposits in this region are excellent for use as coarse aggregate for both cement and bituminous concrete. In this section, the Arkansas River is the chief source of sand and gravel. In general, it is of good quality and within a reasonable

distance of a considerable mileage of main-travelled roads. The deposits along this river are chiefly derived from the Pre-Cambrian granite, with some calcareous material from the vast limestone beds found in this region.

South of this river the deposits of gravel are few and generally poor in quality. They are derived from Pre-Cambrian granite, trap, limestone and shale. They usually contain a large amount of silt. In places, gravel will be found composed entirely of limestone particles. These are suitable for surfacing and, when washed, will prove satisfactory for concrete work, provided the particles are hard and sound.

The road-building rocks on the Western Slope are granite, rhyolite, limestone, trap and sandstone, which compare favorably as to quality with the rock deposits on the Eastern Slope. The gravel and sand deposits on the Western Slope are, as a rule, dark colored, due to the presence of trap and grey-granite particles. The gravel is, as a rule, of better quality than that found on the Eastern Slope, but the sand in its natural state is not as suitable for use in concrete as that found east of the mountains. The outstanding fact concerning the Western Slope sands is the high silt content. These sands are mixtures of granite, trap, limestone and shale particles. The silt is composed of clay, loam, limestone, and basalt dust. They can usually be made suitable for use in concrete work by washing. When made into tension briquettes, they show much higher strengths when the silt content is high, and grading normal to fine, than Eastern Slope sands. The reason for this has not been determined, but it is possible that chemical action of the silt and cement may play an important part.

While the seven- and 28-day tensile strength of 1:3 mortars made from many of these sands, which have a normal-to-fine grading and which contain from three percent to ten percent by weight of silt, is very high, the effect of this silt on the compression strength and wearing qualities of concrete made from them is not at this time known. It is, therefore, considered that, on account of this lack of knowledge on the subject, it is better to wash all such sands until they conform to the normal specifications, even though the tensile-strength ratios are high and the strength ratio of the washed material is slightly lower than that of the original unwashed.

The gravel and sand deposits on the Western Slope, as a rule, are suitable for use as gravel surfacing, when the oversize has been crushed so as to pass the one-and-a-half-inch screen. They contain more binding material than the Eastern Slope materials. They are a valuable asset to this section of the State, which is sparsely populated as a whole, and where hard-surfaced roads are not yet economically possible.

Too much emphasis cannot be laid upon the use of tested materials on all kinds of construction. Standard tests are in

use for manufactured materials such as Portland cement and the various types of bituminous materials. Users of these products will protect themselves from one source of possible difficulty by insisting that they be tested before acceptance. These tests should be continued in the standard manner throughout the progress of the work so as to cover all the materials used on the job.

However, important as the above recommendation is, the quality of the natural materials, such as sand, gravel, rock and slag, is equally important, and where the quality of the available natural materials is not known, samples should be taken and submitted for laboratory tests. These should be taken in time to allow at least 35 days between the time of shipment and that when final report is expected. All sampling should be carefully done. When asked to do so, this laboratory will be glad to furnish directions for standard sampling.

After a deposit has been submitted to laboratory tests, control tests may be made in the field, provided the engineer or inspector has suitable equipment. A balance and sieves conforming to the control sieves in the specifications will enable the field man to determine whether the material is up to standard at any time. This equipment will also permit the determination of moisture content with sufficient accuracy for field conditions.

A few twelve-ounce prescription bottles, some two percent solution of tannic acid in 10 percent alcohol, and three percent sodium hydroxide solution, all of which may be purchased at any drug store, permit the test for organic impurities in sands to be made. If a pan 12 inches in diameter and four inches in depth with vertical sides be added to the above, the percent of silt by weight may be determined. The percent of silt by volume is usually sufficiently close for field tests. A 250 c.c., tall, glass graduate is suitable for this. If the percent of silt by volume is determined on the laboratory sample, it may be compared with the percent by weight and will serve as a convenient check as the work progresses.

On concrete construction, the slump test is very important, and can easily be performed in the field. The consistency of the concrete can then be determined and regulated so as to produce a concrete of more uniform quality. A sheet-metal, truncated cone, eight inches on the bottom, four inches at the top and 12 inches high, fitted with foot lugs and handles, together with a small platform on which to perform the test and a puddling rod, is the only extra equipment needed. A description of the method of performing the tests for organic content and percent of silt by volume are given in the appendix. Description of methods of performing the other tests mentioned will be furnished upon request.

The work of sampling and testing the road materials of the State is far from complete, and to that end, the co-operation

and assistance of city and county officials is desired. Any who wish to co-operate are asked to communicate with the Road Materials Testing Laboratory, Fort Collins, Colorado.

APPENDIX I.—STANDARD METHOD OF TEST FOR ORGANIC IMPURITIES IN SANDS FOR CONCRETE

American Society for Testing Materials Serial Designation C 40-22

1. The test herein specified is an approximate test for the presence of injurious organic compounds in natural sands for cement, mortar or concrete. The principal value of the test is in furnishing a warning that further tests of the sand are necessary before they be used in concrete. Sands which produce a color in the sodium hydroxide solution darker than the standard color should be subjected to strength tests in mortar or concrete before use.

2. (a) A representative test sample of sand of about 1 pound shall be obtained by quartering or by the use of a sampler.

(b) A 12-ounce graduated glass prescription bottle shall be filled to the 4½-ounce mark with the sand to be tested.

(c) A 3-percent solution of sodium hydroxide (NaOH) in water shall be added until the volume of sand and liquid after shaking gives a total volume of 7 liquid ounces.

(d) The bottle shall be stoppered and shaken thoroughly and then allowed to stand for 24 hours.

(e) A standard color solution shall be prepared by adding 2.5 c.c. of a 2-percent solution of tannic acid in 10-percent alcohol to 22.5 c.c. of a 3-percent sodium, hydroxide solution. This shall be placed in a 12-ounce prescription bottle, stoppered and allowed to stand for 24 hours, then 25 c.c. of water added.

(f) The color of the clear liquid above the sand shall be compared with the standard color solution prepared as in paragraph (e) or with a glass of color similar to the standard solution.

3. Solutions darker in color than the standard color have a "color value" higher than 250 parts per million in terms of tannic acid.

APPENDIX II.—METHOD SUGGESTED FOR THE DETERMINATION BY VOLUME OF THE PERCENT OF SILT IN FINE AGGREGATE

Use a 250 c.c. graduate filled to the 100 c.c. mark with the sand to be tested and add water until the surface of the liquid stands at the 150 c.c. mark. Place the hand over the top of the graduate and agitate vigorously for a few minutes. Allow to settle for one hour, and determine the depth of silt on top of sand. From this, the percent of silt by volume may be readily computed.

If the sand contains clay, which remains in suspension at the end of the test, the addition of a small amount of a solution of common salt will cause the suspended material to be thrown down much more quickly.

ERRATA

Page 26—3d line under "Remarks": "W.O.K." should read "W.O.K.?"

Bulletin 285 April, 1923

The Colorado Experiment Station

AGRICULTURAL DIVISION

CONTROL OF THE WHORLED MILKWEED IN COLORADO

By W. L. MAY
Deputy State Entomologist



Location of Plots for Chemical Eradication Experiments near Paonia, Colorado.

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The Colorado Agricultural College

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CONTROL OF THE WHORLED MILKWEED IN COLORADO

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When it had been conclusively established in 1918[1] that the whorled milkweed (*Asclepias galioides H. B. K.*) had been responsible for previously unexplained heavy losses of livestock in Southwestern Colorado, it became imperative that control measures be determined to put a stop to these losses. This work was turned over to the author in 1918, who, at that time, was assistant botanist for the Experiment Station, and during that year the work was carried on entirely as a project of the botanical section of the Experiment Station. In 1919, the work was carried on jointly between the botanical section and the State Entomologist's office. Finally, in 1920, under the provisions of the Pest Act and the State Entomologist's Law, the work was transferred to the office of the State Entomologist.

At the time of the transfer of the work, the only project in mind for the writer was the whorled-milkweed problem. Since that time, however, the investigational work on this problem has been completed, and the weed problem of the State is being viewed on a broader basis. There are other pernicious weeds in the State which do not poison livestock, but which probably cause a greater financial loss yearly than does the milkweed, due to the reduction in yield of farm crops and tillable acreage. With the increased value of agricultural land and the rapidly diminishing amount of new land that is available, the weed problem is being viewed with more and more apprehension. Especially is this true where valuable land is being entirely taken by such pernicious weeds as the wild morning glory, perennial peppergrass, poverty weed and Canada thistle. When an acre of valuable land is made valueless by the encroachment of such weeds, the owner realizes his loss, and a demand is made for some means of reclaiming such land, and of preventing more acres from being infested.

The policy of this office has been to take up the investigation of control measures for these worst weed pests as fast as the available funds will allow. We find that there is a remarkable paucity of information as to successful methods to be used against our worst weeds. We find, also that methods highly recommended for other sections, are not always applicable to Colorado conditions, so that it seems we are faced with the necessity of working out control methods applicable to our particular conditions, and in this work, oftentimes, we can merely be guided by the work of others under dissimilar conditions. At the present time, this office is centering its attention on the wild morning glory (*Convolvulus arvensis*) and the perennial pepper-

grass (*Lepidum draba*). Two seasons' work on the former has given us some rather valuable information, but it has not placed us in a position to make any definite recommendations. The work on the latter was just begun the past season.

The weed work of this office has been entirely empirical, that is, a number of methods of attack were outlined and tried out in the field, and conclusions based on the results of this "cut and try" method. The plans are, of course, influenced by the knowledge available of the life history and the physiological activity of the plant attacked, but the writer feels that such knowledge has been altogether too limited, and that the proper control of our worst weed pests will resolve itself into a joint problem for the plant physiologist and the chemist. Particularly is this true of chemical eradication of weeds, where the reaction of chemicals on the soil will also enter in.

In the work on the whorled milkweed it early became evident that the problem naturally divided itself into three parts. The first part of the work was to determine the distribution of the plant, its life history and habits, and to acquaint the livestock owners with the plant so they could recognize it and know it as poisonous. This constituted the major portion of the work in 1918[2]. The results from this educational work were exceedingly gratifying, and since the livestock men have been made acquainted with the plant and the conditions under which poisoning occurs, few heavy losses have been recorded, and the losses of individual animals have been greatly reduced.

The second part of the problem was to determine praticable methods of killing out the plant on tillable land, and the third part was to work out a chemical treatment that could be applied on waste land of little value, where cultivation methods could not be applied, where the milkweed was a constant menace to stock, and where seed was produced which became a source of infestation on tilled lands.

ERADICATION OF MILKWEED ON TILLABLE LAND

At the beginning of the investigation on the whorled milkweed, many farmers reported extreme difficulty in trying to rid their land of this pest. The plant is extremely persistent by means of very fine, lateral rootstocks and, because of this feature, has proved itself to be in a class with Canada thistle and wild morning glory, although subsequent experimentation has proved that it is not equal to these plants in persistence. Farmers reported that years of hoeing and ordinary cultivation methods had proved of no avail against the plant. The writer at the beginning of the work was imbued with the old established idea that the proper method of attack for all such weeds was to start early in the year and to continually keep the tops cut

off, with the object of starving the roots out. At the end of the experimental work, the writer does not have so much faith in this procedure as a practical method of eradicating such perennial weeds; and in the case of the whorled milkweed, this method is not only a very expensive one to apply, but it is entirely impractical for killing the plant.

Following is an extract from Bulletin 255 of the Colorado Experiment Station:

> Plot IV. Summer Fallow 1918, followed by a Cultivated Crop in 1919. During 1918 this plot was given the following treatment:
> Plowed June 15, with a double-disc plow to a depth of 3 or 4 inches.
> Double disced June 26.
> Double disced July 8.
> Plowed with tractor 8 inches to 10 inches deep July 23.
> Double disced August 26.
> Double disced September 20.
> Double disced October 15.

The principle followed in this treatment was to keep the plant from having any green leaves during the season; at no time was the milkweed allowed to form any green leaves. As soon as a very few showed through the surface the plot was double disced. The persistence with which the roots continued to send up stalks through the soil was remarkable. It must be remembered that no rains fell during the period from June 1 to September 1, and that by the latter date the upper 8 inches of soil were as dry and as porous as an ash heap. Every bit of milkweed in this upper layer was dried up and dead but the roots below the furrow slice continued to send shoots to the top of the soil through the dry dirt until fall. (Fig. 1). In most cases these roots were about the size of ordinary binding twine or smaller, and yet enough shoots were sent up to make the stand as thick as it was originally.

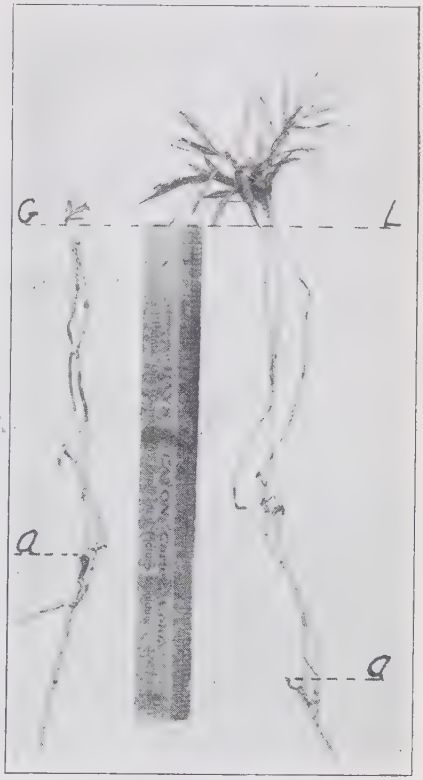


FIG. 1.—Growth made on Plot IV at Cortez from July 20th to August 20th, 1918. A and A are the points at which the old plants were cut off. G D is the ground line. The growth was made after the treatment outlined in text.

From May 16 to May 20, 1919, this plot was double disced and harrowed. On May 20 part of the plot was planted to potatoes and part to corn. These two crops were treated as follows during the season:

> Hoed June 10.
> Hoed June 26.
> Cultivated three times over July 25.
> Cultivated August 10.

The crop was given the treatment of an ordinary farm crop, with the exception that a little more care was given.

The rainfall during the 1919 season was considerably greater than in 1918, but the corn and potatoes were not irrigated. **Despite this treatment the milkweed was thicker in 1919 than it had been at the beginning of the experiment in 1918.** The potato and corn crops were not in any way held back by the milkweed. In fact, due to the summer fallow the previous year, the crops were very good. (Fig. 2). The experiment was a good demonstration, proving conclusively that thorough work, begun early and continued throughout the season, and followed the next year by a hoed crop, is inefficient as a means of eradicating milkweed.

The conclusions from the above are obvious, and these results have been substantiated numerous times by the experience of farmers who have followed a similar method in attempting to rid their land of this pest.



FIG. 2.—Corn crop in Plot IV, August, 1919. Note small milkweed in foreground.

Two other plots, in which the work was based on the principle of attacking the plant just before the maturing of the seed, at which time the roots are most completely sapped of their stored food, gave much more encouraging results. One of these plots was grubbed with a grub hoe just as the plants were beginning to form pods on July 15, 1918. By "grubbing" is not meant just the digging up of that portion of the soil immediately surrounding the shoots which are visible above ground. All the soil was moved to a depth of eight inches, entirely across the plot, and extending for at least a foot beyond any visible green shoots on all sides

of the patch. A second such grubbing was given on August 23, when it was estimated that the plot was showing 3 percent of the original stand. The following year twelve spindling shoots of milkweed made their appearance on a plot 50 feet long by 8 feet wide, where the previous year the ground had been entirely covered with milkweed. This is almost 100 percent control. In 1919 the ground was completely covered by a stand of horsemint which came from seed from a neighboring patch.

Almost identical results were obtained on a plot which was plowed on August 1 and again on September 2. In this case the control was not so good as where thorough grubbing was done, but at least 90 percent of the original stand was killed.

Based on the conclusions from the above experimental work, it was recommended to farmers that they try a late summer plowing followed by an early fall plowing and seeding to winter wheat where practicable. Those who tried this plan have in every case reported successful control. In bad infestations it was necessary to continue the treatment another year. Some farmers have reported excellent results by late fall plowing after seeding time, even as late as October, this treatment being repeated for another year. This method was followed by some men in an effort to cover up the milkweed in their pastures before turning sheep in, and much to their surprise, two years of the treatment killed out practically all of the milkweed, and this in some cases on patches where previously a very careful and painstaking job of summer cultivation had been followed and the killing of the plant given up.

RECOMMENDATIONS FOR ERADICATION ON TILLABLE LAND

From the four years of experimental work, and the observations made on the work of farmers on their own farms, the following recommendations are made to be applied on lands that are tillable:

(1) Do not attempt to kill out whorled milkweed by beginning early in the season and cutting off the tops continously throughout the season. It is work wasted.

(2) Leave the milkweed entirely alone in the early part of the season and begin eradication work just before seeding time.

(3) On large patches, plow thoroughly just before seeding time, and again in early fall and, where possible, establish a good stand of winter wheat. It is rather important that the soil be occupied as soon as possible by a crop that shades the ground. Avoid a cultivated crop the next year. It will usually be necessary to repeat the late summer or fall plowing the following year.

(4) For small patches where plowing is not practical, a treatment based on the same principle may be given, a grub hoe or a spade being substituted for the plow. (Fig. 3.) Remember that in plowing, all the soil is moved, and in grubbing or



FIG. 3.—Method of grubbing small patches. Note bank to be worked to.

spading, every portion of the soil must be moved, if desirable results are obtained. A second treatment may be given if green shoots make their appearance.

EXPERIMENTS WITH CHEMICAL SPRAYS

It was found that there are many acres of whorled milkweed growing on hillsides which cannot be cultivated, and where the nature of the soil will not permit of any grubbing work. Particularly is this true of rocky hillsides below irrigation ditches in Western Colorado (Fig. 4). The only method which seemed to offer any hope of success in eradicating such areas was the use of a herbicide. Letters of inquiry to various experiment stations revealed the fact that very little of a definite nature was known as to the successful use of herbicides against perennials.

Perhaps the most successful general use of any herbicide is that of iron sulphate against the mustards, particularly in grain fields. This had its beginning in the work of H. L. Bolley in North Dakota. Other chemicals which have been given a trial as herbicides, with more or less variable results, are copper sulphate, common salt, crude oil, sulphuric acid, carbon bisulphide and sodium arsenite.



FIG. 4.—The type of milkweed patch that can be eradicated only by chemical treatment.

Of all these, the latter is probably the most potent. It has been used to a considerable degree in Hawaii[4], especially where the rainfall is excessive and working of the soil would result in puddling. Considerable experimentation was carried out in California by George P. Gray on the use of sodium arsenite in the eradication of wild morning glory[5]. His results were very good in the fog belt, but he could not duplicate these in the arid section[6].

Practically all the commercial weed-killers on the market are composed either entirely or in large part of sodium arsenite. The use of this chemical is attended with the undesirable feature that when applied in appreciable quantities it poisons the soil and makes it sterile, and there is always the danger of poisoning livestock where foliage is sprayed with an arsenical. These features will limit the use of arsenical weed-killers to untilled land or land of little value, or, in extreme cases, to tilled lands which are made valueless because of being totally occupied by pernicious weeds and where it is desired to kill out the weed at any cost to prevent further spreading. They may also be used on roadsides, rights-of-way or other places where no vegetation is desired.

Much of the milkweed which it is desired to eradicate occurs on rocky hillsides (Fig. 4) along stock driveways where it is a constant menace to stock being driven down to the lower valleys in the fall. Furthermore, these areas are in the lower

valleys where there is no loose stock during the summer months when there is the most danger of poisoning from the sprayed foliage. It was found that the foliage which had been sprayed was so dried up by the time the stock came down in the fall that there was none of it eaten. In addition, these areas have been responsible for so much loss, and are still such a menace to stock, that any sure method of eradication would be a paying investment even though the cost was apparently rather excessive.

SPRAYING EXPERIMENTS OF 1920

General Plan:—During 1920 the plan of the work was to try out a number of different herbicides with a view to determining the one which gave the most promise of success. With this in mind the following chemicals were used at the beginning of the season:—Iron sulphate, copper, sulphate, crude oil, common salt, sodium arsenite and two commercial weed-killers, whose active ingredient is sodium arsenite.



FIG. 5.—Type of soil in which much milkweed occurs in Western Colorado, and where eradication by cultivation cannot be applied.

Plots one square rod in area were laid out on a hillside two and a half miles west of Paonia, where the occurrence of the milkweed was typical of the areas which cannot be successfully

eradicated by cultivation methods. The soil there is very rocky, as shown in Fig. 5.

All chemicals were applied in the form of a fine spray, a Meyers hand spray pump being used. No attempt was made to soak the soil and kill the plants by the root absorption method, but the tops only were completely covered. Because of the smooth epidermis of the milkweed leaves and stems, one-eighth pound of linseed-oil-jelly soap per 5 gallons of solution was added to all the sprays, except the sulphate and the commercial weed-killers. In the case of the sulphates the soap forms a very sticky precipitate which clogs up the machinery. Furthermore, the sulphate is broken down by the chemical reaction between it and the soap which would make it inefficient as a herbicide.

Iron Sulphate.—To each square-rod plot treated with this chemical a solution of 10 pounds of ferrous sulphate to 5 gallons of water was applied. In all, three plots were treated with this chemical, and in no case were the tops even completely killed. The killing was so small as to cause it to be discarded early in the season.

Copper Sulphate.—The solution for each square rod was 5 pounds of the copper sulphate to 5 gallons of water. The results were identical with those obtained from the use of the iron sulphate.

Crude Oil.—Each square-rod plot was treated with three-fourths of a gallon of oil, two and a fourth gallons of water and one-eighth pound of linseed-oil-jelly soap to make a good emulsion. This application killed all the tops of the plants, but there was no absorption into the below-ground portions, the killing being limited to the portions covered with the oil. Growth was immediately resumed from the roots. While the use of this material was continued through most of the season and a number of plots were treated, the results would not warrant even the continuation of experimental work for another season.

Common Salt.—Several applications were made using ten pounds in five gallons of water. In no case was there any appreciable killing of the milkweed plants.

Sodium Arsenite.—A stock solution of sodium arsenite was made as follows: Three pounds of sal soda (sodium carbonate) were dissolved in boiling water and one pound of white arsenic was added and boiled from twenty minutes to half an hour. Enough water was used to make two gallons. From this stock solution, dilutions were made for application upon the various plots. There were four series of plots based on the amounts of white arsenic per acre used in the applications. The application on Series 1 was equivalent to 8 pounds of white arsenic per acre; on Series 2, 12 pounds per acre; and on Series 3, 16 pounds per

acre. In these three series, 5 gallons of the diluted solution were applied to each plot. On Series 4, 10 gallons of material containing 1 pound of white arsenic were applied per square rod.

In every case the tops of the plants on the plots were entirely killed, but in the case of the lighter solutions, there was practically no absorption into the roots, even though on some plots as many as three applications were made during the season. The amount of absorption did not seem to increase at all as the season advanced. In case of Series 4, however, both with single applications and with two applications during the season, practically all the roots were killed, and, as late as the fall of 1922 two of the plots in this series had no more than four or five plants of milkweed on them, where previously the ground had been entirely covered. These few plants are showing no signs of spreading, and in every case they are coming up from under large rocks where the roots were evidently not reached by the applications.

The killing of the tops by this chemical was very quick and very thorough, but there was no absorption into the underground parts of the plant where small quantities were used as reported by Mr. Gray in his work on the morning glory in California. Where the large quantities were used, however, the roots were killed as far as any roots could be found in the soil, some of these going to a depth of about 14 inches, and in many cases lateral roots eight or ten inches beneath the surface were killed for a distance horizontally of 18 inches from the clump of stems to which the material was applied.

Commercial Weed-Killers.—Two commercial weed-killers were used. One of these, according to analysis by the chemistry department of the Colorado Experiment Station, contained approximately three and one-fourth pounds of white arsenic per gallon, the other contained almost four pounds white arsenic per gallon. The first of these was diluted at the rate of one-fourth gallon of the weed killer to four and three-fourths gallons of water, the second at the rate of one-half gallon to nine and one-half gallons water. These were the dilutions advised by the manufacturers. The ten-gallon application was heavier than was really necessary to cover the plants, but the five-gallon application did not allow of any appreciable amount of material getting onto the soil. These applications correspond to applications of 125 and 300 pounds of white arsenic per acre. The excessive amount did not give any better results than did the application of the prepared sodium arsenite corresponding to 160 pounds of white arsenic per acre. The applications at the rate of 125 pounds of white arsenic per acre did not give as good results as the 160 pounds per acre.

The roots on the plots treated with the commercial weed-killers were killed to a depth of six inches to a foot into the ground. The plots treated with the weaker weed-killer showed no appreciable control in 1921, but the plots sprayed with the stronger weed-killer showed from 50 to 85 percent killing in 1921.

Conclusions.—At the beginning of the work for the 1920 season, there was very little information to guide the planning of the work. It was necessary to do a good deal of guessing as to the methods of attack that would be likely to produce results. As a result, the season's work only served to clear the field to a certain extent and to serve as an indicator of what line of procedure followed in 1921 would give the most promise of success. It was clearly demonstrated that, of all the chemicals tried, only one, sodium arsenite, was giving results that would warrant the continuance of its use in 1921. It was shown also that applications of more than 16 pounds of white arsenic per acre would be necessary to accomplish the desired results, while such excessive amounts as 300 pounds of white arsenic per acre were apparently no more effective than 160 pounds. The optimum strength seemingly lay between 16 pounds and 160 pounds of white arsenic per acre.

SPRAYING EXPERIMENTS OF 1921

In accordance with the results of the 1920 experiments, the only chemical retained for use for the 1921 season was sodium arsenite. This material was bought in the form of a thick, sirupy solution, which is a by-product of the smelting industry, the white arsenic from the smelting being combined with a solution of sodium hydroxide. The sodium-arsenite solution bought was guaranteed to contain eight pounds of white arsenic per gallon.

General Plan of Work.—The objects sought in the season's work were to determine, first, the most efficient strength of solution to use; second, the best time in the development of the plant to make the applications; and third, the comparative efficiency of dilute solutions begun early and repeated through the season, and of heavy solutions made late in the season.

With these objects in mind, the following method was pursued:

Stock Solution: A stock solution was prepared by adding to one gallon of the sodium-arsenite solution as purchased, seven gallons of water, making eight gallons of a stock solution containing one pound of white arsenic per gallon.

Strengths of Solutions Used.—Square-rod plots were grouped into seven series, lettered A to G, respectively, and the applications for these plots made according to the following table:

Series A— ½ gal. stock solution plus 4½ gal. water
Series B—1 gal. stock solution plus 4 gal. water

Series C—1¼	gal.	stock solution	plus	3¾	gal. water
Series D—1½	gal.	stock solution	plus	3½	gal. water
Series E—2	gal.	stock solution	plus	3	gal. water
Series F—3	gal.	stock solution	plus	3	gal. water
Series G—4	gal.	stock solution	plus	4	gal. water

It will be noted that in series F and G the dilutions are the same, but that the amounts applied are not the same. Those two series were begun on July 28, when the plants were in the pod stage, and were made for the purpose of testing the efficiency of copious applications made only once, late in the season.

To each five gallons of solution applied, a lump of linseed-oil-jelly soap was added to act as a spreader and sticker. This soap served very well to bring about even spreading and sticking to the smooth surface of the milkweed plants.

Method of Application.—All applications were made with a small, hand, spray pump mounted in a twelve-gallon galvanized can, which in turn was mounted on handles and a wheel so that it could be moved as a wheelbarrow. A Bean Majestic nozzle of the whirlpool type was used with a six-foot rod made from a

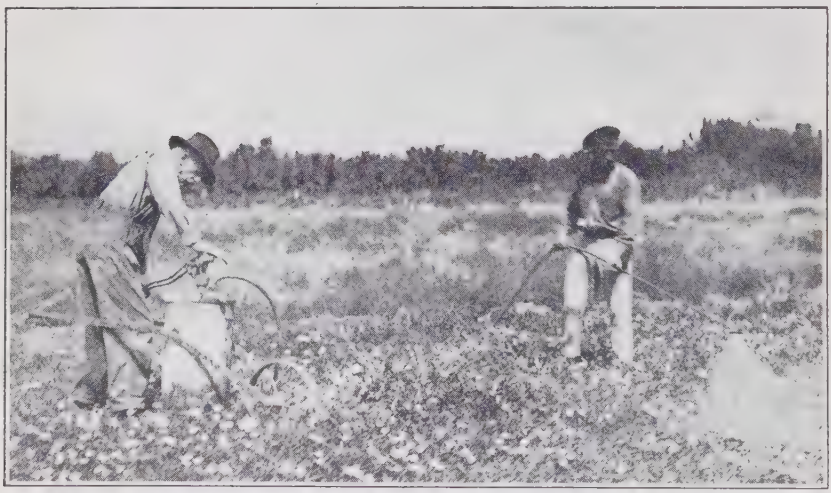


FIG. 6.—The outfit illustrated in use on wild morning glory is the same one used in the experiments on the whorled milkweed.

piece of three-eighths-inch pipe. The nozzle was angled so that the spray was directed downward. With this outfit, a very fine spray could be made, one man operating the pump and the other using the rod. (Fig. 6). A special effort was made to keep the spray in the form of a fine mist that would evenly cover the plants. No effort was made to wet the soil, the tops only being sprayed. A certain amount of the material, of course, got to the

soil, especially in series F and G, but in no case was the soil appreciably wetted.

Numbering of Plots.—Each plot was designated by its series letter, and the number representing its consecutive place in the series as shown by the date of the first application to the plot. For example, the first plot in Series A received its first application on June 9, and it was designated as Plot A1; the second plot in this series was sprayed for the first time June 25, and was designated A2, and so on.

Location of the Plots.—The plots for the 1921 work were laid out on the same hillside as were those for 1920.

Weather as a factor.—It is thought that rainfall and relative humidity have an important effect upon the action of chemicals upon plants. Following is a summary of these two factors for Paonia for the 1921 season.

There was an exceptionally large amount of rainfall for this section in 1921. In June there were eight rainy days; in July, 9; in August, 9; and in Septmeber, 4. In June, July and August, the rainfall was considerably above the normal, while in September it was below the normal for the section. In June there were 1.79 inches rainfall; in July, 1.97 inches; in August, 1.95 inches; and in September, 1.06 inches. The normal rainfall for Paonia over a 29-year period up to 1921 was as follows: June, 0.54 inches; July, 1.03 inches; August, 1.25 inches; September, 1.33 inches.

Following is the rainfall as it occurred at Paonia during the four months:

June	July	August	September
4—.40 inches	4—.37 inches	1—.27 inches	1—.93 inches
5—.02 inches	9—.08 inches	9—Trace	15—Trace
6—.13 inches	12—.11 inches	10—.30 inches	17—.10 inches
7—.61 inches	13—.04 inches	14—.10 inches	28—.03 inches
9—.03 inches	15—.13 inches	16—.08 inches	
13—Trace	18—.26 inches	21—Trace	
14—Trace	22—.30 inches	22—.60 inches	
15—.60 inches	26—.56 inches	24—.55 inches	
	31—.12 inches	25—.05 inches	

The relative humidity for this section is always low. In 1922 the relative humidity for Grand Junction compared very closely with relative humidity records kept at Paonia. It is probably safe, for comparison of Paonia with other general sections of the country, to assume that the relative humidity at Paonia is very close to that at Grand Junction, it probably being a little higher at Paonia. The monthly relative humidity for Grand Junction was as follows: June, 40, or 8 percent above normal; July, 47, or 11 percent above normal; August, 56, or 16 percent

above normal; September, 36, or 6 percent below normal. Despite the fact that the rainfall and relative humidity for 1921 were above the average for Paonia, it must be borne in mind that this section would be considered as arid, especially during the summer months, as the heavy precipitation comes during the winter months. At all times the relative humidity is always low enough to cause rapid evaporation of spray from the plants.

Development of Plants as a Factor.—It is indicated that this will be an important factor in the killing of plants by the use of chemical sprays. In order to prevent the repetition of the same information applicable to a number of plots, a summary of the development of the milkweed plants on the different dates of spray applications is given at this point.

On June 9 a small percent of the plants were showing buds, others were just about an inch high or just breaking through the ground, and some shoots had not reached the surface.

On June 25 the plants were in the budding stage, a very few umbels beginning to show open blossoms. The plants were thrifty and growing rapidly.

On July 15 the late-blossoming stage had been reached, practically all the flowers being open, and in a few cases the petals of the lower flowers had fallen.

On July 28 a few of the lower pods were about two inches long and not yet filled out. The last of the upper buds had opened.

On August 11 the pods were two to three inches long, a very few beginning to burst. Vegetative activity had practically ceased.

On September 3 the pods were shedding seed. About 50 percent of the pods had burst.

RESULTS BY PLOTS

Plot A1.—First application, June 9; 100 percent of tops killed and dried up June 11.

Second application, July 15; 90 percent of original stand returning at time of application; all tops killed July 17.

Third application, August 16; 90 percent of original stand returning; new growth three inches to six inches high; all tops killed August 18.

On September 29, 1921, it was estimated that there was 90 percent of the original stand returning. The older roots, especially the larger and woodier ones, had been killed to a depth of three to four inches, and in some few cases of tap-rooted specimens, plants were killed completely. In most cases, digging revealed new growth coming from the point where the roots branched horizontally.

During the 1922 season the plot showed 80 percent of the original stand. Individual plants showed from one to three healthy stalks. The seeding was normal. Grass (*Hilaria jamesii*) and horehound (*Marrubium vulgare*) plants were apparently uninjured.

Plot A2.—First application June 25; 100 percent of tops killed June 28.

Second application on August 16; 60 percent of original stand returning; new growth six inches to eight inches high; all tops killed August 18. On September 29, 1921, digging showed that spray had killed the roots to a depth of two to six inches, but growth was resumed from below these points. A few taprooted plants were killed. On October 16, 1922, it was estimated that the plot had 80 percent of the original stand of milkweed.

Plot A3.—First application July 15; all tops killed July 18.

Second application on August 16; new growth 100 percent of original stand about 3 inches high; all tops killed August 19. During the 1921 season, about 50 percent of the original stand returned, and in 1922, 55 or 60 percent of the original stand returned.

Plot B1.—First application June 9; all tops killed June 11.

Second application August 16; 60 percent of original stand returning, mostly from horizontal roots between the old crowns; returning growth six inches to eight inches high; all tops killed August 18.

On September 29, about 5 percent of the original stand was returning, and this mostly from between the old crowns, only four or five of the latter showing any green shoots. Digging showed that all new growth was returning from at least 6 inches under ground; that is, all old roots had been killed to at least this depth.

On October 16, 1922, not over 5 percent of the original stand was present on the plot. Eleven shoots on the plot made seed in 1922. A few plants of *Hilaria jamesii* and horehound were growing normally on the plot.

Plot B2.—First application, June 25; all tops killed June 28

Second application, Sept. 3; all tops killed. There is what would seem to be a discrepancy in the notes on this plot. At the time of the second application, the returning growth was estimated at 40 percent of the original stand. On September 29, the returning growth was estimated at 90 percent of the original, and it was very clear that the second application had done no root killing. During the 1922 season, it was estimated that there was 60 percent of the original stand in 1921.

Plot B3.—First application, July 15; all tops killed July 18.

Second application, September 3. The returning growth was

two to seven inches high and estimated at 50 percent of the original. All tops killed September 5. It was estimated in 1921 that 80 percent of the plants had been killed, but on October 16, 1922, it was estimated that 60 percent of the original stand had returned.

Plot B4.—First application July 28; all tops killed August 1. No second application. The roots on this plot were in no case killed to more than two inches below the surface. In 1922 the stand was entirely uninjured.

Plot B5.—Application made August 11; all tops killed August 14.

In 1922 the stand showed no injury, 100 percent of a stand being present on October 16, 1922.

NOTE:—For this plot and for all plots sprayed on or after this date, it was impossible to make any estimate of root killing in 1921, as it was so late in the development of the plants, that even though the roots were not killed, very little returning growth was made in 1921. The estimates of control for this and plots sprayed later were based entirely on growth that returned in 1922.

Plot B6.—Application made September 3; all tops killed. On August 2, 1922, the stand showed no injury.

Plot C1.—First application, June 9; all tops killed June 11. Second application, August 16; returning growth was estimated at 50 percent of original stand.

On September 29, there were only six green shoots of milkweed on the plot, and all but one of these were coming from small, horizontal roots between the old crowns. During 1922, the plot remained totally bare except for seven weak shoots of milkweed, and a half dozen small clumps of *Hilaria jamesii*. The killing was at least 98 percent.

Plot C2.—First application, June 25; all tops killed June 28. Second application, September 3; all tops killed. On September 29, the plot showed 85 per cent of the original stand. Roots were killed two to four inches into the ground. During 1922, it was estimated that 50 percent of the original stand was present.

Plot C3.—First application, July 15; all tops killed July 18. Second application, September 3; 40 percent of original stand returning; new growth two inches to seven inches high, larger plants just budding; all tops killed September 5.

On October 16, 1922, the control was estimated at 80 percent.

Plot D1.—First application, June 9; all tops killed June 11. Second application, August 16; two percent of original stand returning; new growth in early blossom stage; all tops killed August 18. On September 29, only two green shoots were showing on the plot. Rotted roots were dug up to a depth of a foot and to a distance of 18 inches horizontally.

In 1922, the plot remained entirely bare except for two small

shoots of milkweed and a small amount of grass (*Hilaria jamesii*) at the bases of rocks where it was difficult to reach with the spray. Control was almost 100 percent. (Fig. 7).



FIG. 7.—In the foreground, Plots D 1 and E 1 sprayed in 1921. Picture taken late August, 1922, showing no returning growth as against heavy growth on check in background.

Plot D2.—First application June 25; all tops killed June 28. Second application, September 3; new growth estimated at 50 percent of original stand; three inches to eight inches high; all tops were killed.

During 1922, the estimated control was 85 percent.

Plot D3.—Application made July 16; all tops killed. On September 29, digging showed that the roots had been killed to the horizantal branches, and that the killing had extended for a few inches along the latter, but enough new sprouts were coming from the unkilled portions to make 50 percent of the original.

Plot D4.—Application made July 28; all tops killed. Roots were killed to a depth of two to four inches below the surface, but growth from below this point was resumed very quickly. During 1922, the stand was apparently uninjured.

Plot D5.—Application made August 11; all tops killed. During 1922, about 80 percent of original stand returned.

Plot D6.—Application made September 3; all tops killed. This plot showed no returning growth worth while spraying in 1921, but in 1922 the stand was apparently uninjured.

Plot E1.—First Application made in June 9; all tops killed June 11.

Second application August 16; 50 percent of original stand returning; new growth in early blossom. During September,

1921, there were four new shoots on the plot. These apparently had begun growth but were below the surface at the time of the second application. During 1922, no milkweed or other weeds grew on this plot. It remained entirely bare during the entire year.

Plot E2.—First application June 25; all tops killed June 28. Second application September 3; returning plants 60 percent of original stand; new growth 3 inches to eight inches high; some blossoming. The control on this plot in 1921 was estimated at not more than five percent, but in 1922 only twelve plants showed up on the plot and the control was estimated at 95 percent.

Plot E3.—First application July 15; all tops killed July 18. The growth which returned on this plot was very slow in starting, and it was estimated in 1921 that 90 percent of the roots were killed. In 1922, however, about 50 percent of the original stand returned from small horizontal roots between the old crowns.

Plot E4.—Application made July 28; all tops killed August 1. It was estimated that the returning growth on this plot on October 8, 1921, was 90 percent of the original stand. In 1922, the killing was estimated at 40 percent.

Plot E5.—Application made August 11; all tops killed August 14; practically no returning growth in 1921. Control was in 1922 estimated at 50 percent.

Plot E6.—Application made September 3; all tops killed September 5. The stand in 1922 was 100 percent of the original.

Plot F1.—Application made July 28; all tops killed August 1. In 1921, the estimated returning growth was 15 percent of the original. In 1922, the control was estimated at 75 percent.

Plot F2.—Application made August 11; all tops killed August 14.

Control estimated in 1922 at 95 percent.

Plot F3.—Application made September 3; all tops killed. Control in 1922 estimated at 50 percent.

Plot G1.—Application made July 28; all tops killed August 1. Digging of roots in 1921 showed all roots rotted. In 1922 three small plants showed up on the plot, a control of at least 99 percent.

Plot G2.—Application made August 11; all tops killed August 14.

Control estimated in 1922 at 95 percent.

Plot G3.—Application made September 3. All tops killed September 6.

Control estimated in 1922 at 95 percent.

DISCUSSION OF RESULTS

While a study of the foregoing notes on the individual plots treated shows some discrepancies in results on some of the plots, there are apparently some rather general conclusions that may be drawn as to the efficient strength of solution to be used, and the time of application.

It is not worth while considering any application which does not show practically 100 percent killing. A checking over of the results on the various plots shows that there are ten of the thirty plots treated which show a control of 90 to 100 percent. These plots are B1, C1, D1, D2, E1, E2, F2, G1, G2 and G3. The solution in Series A, which was equivalent to an application of 80 pounds of white arsenic per acre was entirely too weak to give any worth-while control. From an examination of the data on these plots certain conclusions are obvious:

First.—Stronger applications of sodium arsenite are required as the season advances to kill even the tops of the milkweed. This is evidenced by the fact that only in the series receiving very heavy applications was there appreciable control where the first application was made after the plants had reached the blossoming time. In all the series, except Series A, very good control was obtained where the first application was made on June 9, when only the very first shoots to come up were beginning to show buds, and the second application was made from the middle of August to early in September, when the returning growth was just beginning to blossom. It is rather strange that the same control was not obtained where the applications were made to plants previously unsprayed and which were in the same stage of development as were the returning plants on plots previously sprayed once. This might be partly explained by the fact that the new growth on plots sprayed once came back largely from horizontal rootstocks between the first crowns which were killed back. This growth may have sapped the horizontal under-ground portions so that the second application completed the killing and the absorption through the new growth was sufficient to reach the remaining horizontal rootstocks.

Second.—The most economical single application, which gave 95 percent control, was made on Plot F2 on August 11, when the plants had practically ceased vegetative activity and the pods were two to three inches long with some of them beginning to burst. The same application made on Plot F1 on July 28, gave a 75 percent control, while an application made to F3 on September 3, when the plants were practically through all activity and most of the seeds were shed and all matured, killed only 50 percent of the plants. The single applications in Series G, each of which is equivalent to the application of 640 pounds of

white arsenic per acre, killed the milkweed practically completely, but such an application is out of the question to be used in a practical way, except in the case of a very small patch which is a menace to agricultural land and which it would be desired to kill at any cost. In such a case this treatment might be used, but the results on other plots show that it is not necessary to use such drastic measures.

Third.—It would seem that the best chemical method to use in attacking the whorled milkweed, as indicated by the results of the spraying at Paonia, is to start with the first application early in the growth of the plants at about the time the earliest plants are beginning to form flower buds. At this time there will be quite a number of shoots not yet through the ground. The new growth may then be allowed to get to the early blossoming stage and a second application made.

This second application probably need not be so heavy as the first, as in making all applications the effort is made to wet only the above-ground parts and not to soak the soil, and the second growth will probably not be over the entire plot. With this method of treatment, the dilution made in Series B was very efficient, but a stronger solution is recommended. Where five gallons of solution was applied to a square rod, which amount thoroughly wetted a heavy 100-percent stand of the milkweed, the application in Series B was equivalent to 160 pounds of white arsenic per acre. A stronger solution is more certain of results. It would probably pay to use as a minimum the strength of solution used in Series C, which was equivalent to 200 pounds of white arsenic per acre. In making applications over a large area there would probably not be five gallons used per square rod, so that this would reduce the amount per acre. The dilution used in Series C is a dilution of 1 to 32 of the original commercial weed-killer, containing 8 pounds of white arsenic per gallon.

Fourth.—The method outlined above should give good results in killing the whorled milkweed in the arid sections, but it is recommended for use only on such areas as are causing losses of livestock, or on patches along ditch banks which are a source of seed to be carried down onto agricultural land. **In no case should it be used on tillable land, as the cultivation method of control is far the cheaper, and there is not the danger of poisoning the soil.** Even though serious poisoning of the soil did not take place, the cultivation method will leave the soil in much better tilth. It must be borne in mind that the expense of applying the above treatment will be greater than the value of the land, and the only consideration which justifies its use is the prevention of livestock losses, or the prevention of seeding of agricultural land which might finally result in livestock losses.

SOME GENERAL OBSERVATIONS

Growing out of the work on the whorled milkweed there are some indications of general application with reference to the use of sodium arsenite as a herbicide.

First:—It is evidenced that in our arid sections much stronger solutions of the sodium arsenite are necessary to obtain desired results than are required in the moist sections where the relative humidity is high. This is probably due to the fact that the evaporation of the solutions from the plant is much more rapid in the arid sections so that the chemical does not stay in solution so long. Arguing from this premise, it would seem that if an application were made late in the evening, or during a damp period of weather, the results would be better. This might explain the difference in results between the plots receiving the first applications on June 9, and those receiving the first applications on June 25. The former date was during a rainy spell, while the latter was about in the middle of the longest dry spell of the season. There was no difference, however, in the weather conditions at the time of the second applications to the above groups of plots, nor did plots sprayed during rainy periods later in the season show any appreciable advantage over those sprayed with the same strengths of solution during dry periods. This would indicate that the development of the plants is probably as potent a factor as is the relative humidity.

Second:—The good herbicidal value of sodium arsenite should warrant its use on annuals along fence rows, ditch banks, roadways, rights-of-way, and such places, which are commonly breeding places of weed seed, which later infest agricultural land. For young annuals a very dilute solution could be used. The strength used in Series A in these experiments should be very efficient. This solution contained one pound of white arsenic in ten gallons of water. An application would require only enough to thoroughly wet the tops of the plants.

Third:—From the results on the different types of plants on the whorled milkweed plots, it is indicated that these weaker solutions might be very efficient against tap-rooted and woody-rooted types of perennials. Occasionally the milkweed grows as a tap-rooted plant. All such individuals were readily killed by all the different strengths of solution used. Where especial effort was made to thoroughly wet the plants of horehound (*Marrubium vulgare*) which were present on pactically all the plots, all solutions used killed the plants in almost every case. The greatest difficulty experienced was in killing the finer roots and rootstocks which run horizontally through the ground and which are characteristic of the milkweed. It was from these roots between the old crowns that most of the returning growth

came after an application. Little difficulty was experienced in killing the roots down to the point of horizontal branching, but the poison did not follow the horizontal branches readily.

Caution:—In the use of sodium arsenite it must never be forgotten that it is extremely poisonous, and it must be used with all the care possible. Livestock seem to show a preference for arsenical-sprayed foliage, so care must be used to keep them away from it. It must also be remembered that large amounts of this chemical are toxic to the soil.

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A PECULIAR SOIL CONDITION IN THE SAN LUIS VALLEY

By

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A PECULIAR SOIL CONDITION IN THE SAN LUIS VALLEY

By Wm. P. Headden

The writer is aware of the fact that many persons consider the alkali question one of very great importance to many cultivated sections of the West, or perhaps better, of semi-arid sections. I was as fully convinced of this many years ago as these parties are now, but long and varied observations have led me to adopt a most conservative attitude toward our supposed knowledge upon this subject.

In many instances our ranchmen are confronted with very perplexing results brought about by conditions either illy or wholly unknown to them or to anyone else. In such cases the cause of these unexpected results is naturally attributed to any observable and unusual factor in the case, whether it is in any way responsible for the results or not. This is not simply a case of human nature attributing, in ignorance, results to certain causes, but is often an attitude assumed by well-informed persons who do not doubt the correctness of their observations and do not endeavor to ascertain whether they have observed all the facts or whether their interpretations are really legitimate or even rational. I know of the expenditure of years of labor to demonstrate that certain things were facts which had already been demonstrated to be wholly fallacious, though in conformity with popular ideas and preconceived notions.

I am not prepared to state that there are no conditions under which our "white alkalis" may do harm, but I have as yet seen no reason for changing my opinion already often published, that under our ordinary Colorado conditions, they do but little or no harm. No one, I think, has been disappointed more often than I have by results in the garden or field different from those that one would expect, due to great abundance of alkalis. This has been the case, too, when there was an excess of water.

We understand by "white alkali" a mixture of the sulfates of soda, magnesia and lime, associated with some sodic carbonate and sodic chlorid. The sulfates of soda and lime are usually predominant, but the sulfate of magnesia is frequently quite abundant.

The case that I wish to present in this bulletin is involved because of the presence of sodic carbonate within the area considered, which is really my justification for discussing the case. Of the presence of sodic carbonate in detrimental quantities within the area, there can be no question.

The soil in some cases becomes very hard to a depth of four inches, or perhaps more, so hard that one has to use a mattock

to start a hole. We know that sodic carbonate is present in the well-waters and that there are many places in the section rendered unproductive by the presence of this salt. The application of sodic nitrate, to some soils, at least, causes them to become hard, due to the formation of sodic carbonate. This is the explanation given and it is probably correct.

In a series of experiments I applied sodic nitrate at the rate of 250 pounds to the acre. This would correspond to 156 pounds of sodic carbonate, provided it were wholly converted into this salt. The nitrate was applied to the surface and harrowed in. The hardening of the soil took place to a depth of about four inches. The ground broke up in cakes on plowing. If we consider it to have been exactly four inches, the 156 pounds of sodic carbonate had hardened one-third of an acre-foot of soil to this extent. I do not know how small an amount of sodic carbonate might produce this effect but, in this case, we have 117 pounds per million of soil, and I doubt whether a much smaller amount would have shown any effect. Knowing



Plate I—Abnormal Alfalfa Roots

these facts, it seemed a reasonable inference that the hardening of the soil in this other case was due to the sodic carbonate.

Another peculiar fact that we observed in this immediate section of country was the very peculiar development of some alfalfa roots. Ordinarily the alfalfa plant develops a very long tap root and a rather meagre system of branching, fibrous roots. The length of this tap-root system will vary with soil conditions and I have never seen it extend very much below the permanent ground-water level. I have seen them penetrate as much as a foot below this level, and in running water I have seen a great development of fibrous roots. I have dug up both alfalfa seedlings and old plants in this section and found nothing unusual except that the roots were short; otherwise they were typical alfalfa roots. In this particular case they were abnor-

mal in that they had gone down seven inches and then flattened out as though they had grown against an iron plate, but had only a very slight lateral development.

The development of these roots presents the question of soil conditions so forcefully that we give some illustrations and shall devote a paragraph or two to their discussion.

Plate I represents four-year-old plants. The stand was good and the yield of hay was good. The depth to the water plane was not ascertained, but in this section the usual depth is three feet or a little more. The subsoil was a coarse sand.

Plate II represents two-year-old plants from another field belonging to the same party, and Plate III represents the same variety of alfalfa grown at Fort Collins. One of the plants in



Plate II—Development of Alfalfa Roots in Better Ground

this plate will be observed to be somewhat branching but to have a strong tap-root, and we did not attempt to follow it further than is shown in the illustration, 3 feet 10 inches. In other instances we have followed such roots to a depth of from 9 to 12 feet.

A bottom view of the root system is given in Plate I to show how sharply the soil conditions terminated the downward development of this root system only seven inches from the surface. In this case there was scarcely a root that penetrated any deeper than this. In Plate II we have a very abnormal development for alfalfa, but it is much better than in Plate I. What may be the cause of these differences is difficult to determine.

In spite of the fact that I had seen alfalfa grown in strongly alkalized land and in very wet land in this same section of country, my surmise was that the roots shown in Plate 1 had encountered a zone so rich in sodic carbonate that they simply curled around themselves, producing the forms shown in the



Plate III—Normal development for same variety of alfalfa

plate. I was satisfied that it was not due to water and the soil is soft and open; besides I have seen alfalfa push its way through a hard conglomerate for more than eleven feet. I have not ascertained the real cause of this deformation. It is certainly not due to excessive water, for water may shorten but does not give rise to such distortion as this; it is not due to sodic carbonate for alfalfa develops normally shaped roots in

other land containing sodic carbonate, and it is not due to the presence of any hard pan, for the subsoil is open and soft.

The hardening of the soil previously referred to and the development of these roots, together with the fact that this sandy subsoil, when placed in a sack where it can dry out well, also became hard, suggested that there might be a relation between the two series of facts. We proceeded upon the assumption that there was a relation, and despite the fact that we had no good reason for supposing that sodic carbonate had produced the deformation of the alfalfa roots, we thought that it did cause the hardening of the soil, so we applied gypsum to the soil in sufficient quantity, as we thought, to ameliorate the condition. It was a complete failure. It produced no result whatever. The ground was just as hard where we applied the gypsum as where we did not, and the alfalfa was no better. This was decidedly an unexpected result.

The soil experimented with was not analyzed, but the subsoil from the alfalfa field became hard on drying. We obtained fresh samples and found that it contained 0.0172 percent sodic carbonate. The best data that I possess on the toxicity of this salt indicates that the limit of the amount necessary to produce injurious effects on vegetation lies between 0.04 and 0.05 percent of the soil, but this may not be the lower limit necessary to produce hardening of the soil. The only data that I have on this point are those already given in the case of our own soil in which 0.012 percent produced a noticeable effect, but it was very much less than that observed in the case of the soil under discussion; besides, the failure of the gypsum to ameliorate conditions suggests some other cause unless we failed to add a sufficient quantity of it, which we did not do, as we added at least five times the amount necessary according to theory. We are willing to concede that it would have been more convincing if we had added twice as much as we did, but as it was the cost of the gypsum applied exceeded the price of some of the neighboring land per acre, and we were attempting to find a practical solution of making this land give profitable returns without excessive cost.

The amount of sodic carbonate in this subsoil was only moderate, much below the tolerance of seedling plants, but probably enough to cause some degree of hardening in a few instances, but the negative results obtained on the application of gypsum, at least, suggests that too much stress should not be laid upon the part played by the sodic carbonate in the case.

The hydrological conditions of the valley are unusual and the soil conditions vary exceedingly within short distances. In a study of the water used in irrigating our lands, especially in the Poudre Valley, we found the amount of change very great and the character of the changes very definite indeed. The water used for irrigating is, in many cases, mountain water; that is, water taken directly from mountain streams. In other

cases, especially during the latter part of the season, it may have been stored in reservoirs. This makes a great difference in the character of the water used. All the water used in irrigating the land in question is mountain water of an exceedingly acid type, as much as forty-three percent of the total solids being silicic acid, more than half of which is in excess of available bases to combine with it.

One of the marked changes in the irrigating waters is the removal of the greater part of this silicic acid and a still larger portion during storage. In what form it may be removed will undoubtedly be influenced by the soil constituents but most probably as silicates of lime, alumina and iron, provided these bases are available, but we know also that it may be removed as silica in cases where it serves as cementing material or builds quartz grains. The waters of the Rio Grande, which are used in irrigating this land, are very rich in silicic acid and the soil itself differs little from the rocks of the mountains whence the waters come. The change in the conditions consists principally in the fact that this acid water is subjected to evaporation from the surface of this soil.

The ground-waters and the well-waters of this section are alkaline, carrying sodic carbonate as their principal mineral constituent. This is true to such an extent that the drain-waters and shallow well-waters differ from one another much less than would be expected. An illustration of this may be found in a water from a fifteen-foot well compared with one taken from a drainage ditch. The well-water carried, of total solids, 302, and of sodic carbonate 67 p.p.m. That from the drainage ditch carried, of total solids, 373, and of sodic carbonate, 68 p.p.m. The water from the drainage ditch where it tailed out over uncultivated land carried 94 p.p.m. of sodic carbonate. In the different content of sodic carbonate in the ditch water, and in the same where it tailed out over the land, we have a rough measure of the amount of evaporation that had taken place. This factor should be taken into account when comparing the ditch-water and the well-water. My information is that this drainage ditch is twelve miles long.

The whole section is an artesian area and the water is all alkaline; the deeper the wells, the richer is the water in sodic carbonate, which in some instances constitutes 90 percent of the total salts held in solution. The range is from 20 percent up to the amount just given.

The history of this water may be of first importance in this connection. There is a vast amount of evidence that water carrying silicic acid in solution has been the agent that converted many sandstones into quartzites and built many sand grains out into crystals. A more generally observed and popularly appreciated fact is the occurrence of silicified tree trunks, stumps and other fragments of vegetation found in great abundance in some sections.

The artesian waters of this section are alkaline and not acid. There is another section of this same valley which is also an artesian area in which the artesian waters are acid, even when coming from depths as great as from 700 to 900 feet. I have not found any of this peculiar hardening of the surface soil in this section.

There are two questions that will undoubtedly suggest themselves, viz., is the soil of the same origin and character? It is of the same origin and essentially of the same character, but there are variations, no more, however, in the one than in the other area.

The second question is: Is the water supply from the same source? The answer is yes, from the mountains surrounding the valley, the rocks of which are gneisses, granites and igneous rocks. There is no difference between the two sections in these respects.

There is a difference in the drainage of these sections, and this on a very large scale. It has persisted since the formation of the valley. Both sections of the valley are full of water, the fact that artesian flows are opened in the floor of the valley at depths as shallow as 75 or even 65 feet attest this fact; also, areas near the margins of the valley where springs issue from the floor of the valley can scarcely be other than artesian waters.

The waters, river, spring, or artesian, in this section are of the same character, i. e. colorless, acid waters holding the same mineral constituents in essentially the same quantities, but they are wholly different from those of the other sections. These waters may be distinguished as brown and white waters; this is a convenient designation but is not a very sharp one, for some of the alkaline waters are not brown, but most of them are.

The question in mind is: Are these facts related to our soil conditions, and how? It may be difficult to give a satisfactory answer to this question even though they are related, and that intimately.

Some of our facts cannot be proved directly and on a small scale, either of means or in time. We cannot prove directly that the one section has been drained in some measure, at least, since the formation of the valley, and that this measure has been sufficient to maintain the present character of the underground-waters of the one section and has had no influence on that of the other section. Unless we have some rather evident facts to indicate that one part does not communicate directly with the other, it is difficult to believe that drainage from one end of a closed valley for very many years, more years perhaps than we can appreciate when expressed in numbers, would not affect the further end when the floor dips but a few feet and that toward the eastern and north-central part of the valley.

The only fact I know that indicates that there is a direct drainage out of the valley other than the Rio Grande is that

more water flows out of the Embudo Canyon than enters it at its upper end. Where this excess outflow comes from is, after all, a matter of inference. The only apparent and probable source of this excess is the San Luis Valley. The adequacy of this outflow now and in the past, to maintain the character of the water in the southern end of the valley, is also a matter of inference based on the great similiarity between the artesian waters of this area and the mountain-waters that maintain the supply. However great the difficulties in the question, there is no question about the existence of two artesian areas, one characterized by colorless, acid, artesian waters and another by artesian waters which are mostly brown and all characterized by an excess of sodic carbonate. A line approximately parallel with the Rio Grande and only a little way north of it is the boundary between these areas.

This is the only river that flows out of the valley and has unquestionably always been the big river of the section, even when there was no valley—only a big lake. This river built its fan across the lake and divided the lake, as it now divides the valley, into two sections, one north of the fan and one south and west of its present course. On the south side this fan limits the southward drainage and has always cut off drainage from the north side. If these views be correct, as we think they are, the north side has been different from the south side so long as the valley floor has existed and has had a set of water conditions peculiar to itself, whose characteristics have become more and more emphasized as the valley has grown older, until they are now wholly different.

The water supplied to the valley by the Rio Grande and other streams is probably identical in character with that which flowed into the old lake. The character of this water is determined by that of the rocks of its drainage area. These have not changed and the water flowing into the valley is accordingly identical in character with that which first filled the lake. This is a highly characteristic mountain water carrying only a comparatively small amount of mineral matter in solution, and this mineral matter is such as water with a little carbonic acid dissolves out of the soda-lime felspars. This latter fact was established by direct experiment using carbonated water and pulverized felspar, an experiment discussed in former publications. The characteristics of these mountain waters are fairly uniform for Colorado, whether the water be from the Poudré or the Rio Grande. An analysis of the Rio Grande will serve our present purpose well, for it represents the actual water supply of the valley.

The amount of mineral matter held in solution was 5.39 grains in each imperial gallon, or 10 pounds of water.

Analysis of Mineral Matter Contained in Rio Grande Water.

	Percent
Carbon	1.685
Silicic acid	43.395
Sulfuric acid	6.096
Carbonic acid	13.352
Phosphoric acid	0.229
Chlorin	0.907
Calcic oxid (lime)	19.845
Magnesic oxid	3.791
Potassic oxid	2.886
Sodic oxid	6.759
Ferric oxid	0.610
Manganic oxid (br)	0.657
	100.212
Oxygen equivalent to chlorin	0.212
Total	100.000

Analysis of a White Artesian Water, Depth of Well 923 Feet. Mineral Matter Held in Solution, 14.07 Grains per Imperial Gallon.

	Percent
Silicic acid	50.202
Sulfuric acid	3.345
Carbonic acid	14.346
Chlorin	0.485
Calcic oxid	2.877
Potassic oxid	1.903
Sodic oxid	23.267
Ferric and aluminic oxid	0.260
Ignition	3.081
	99.766
Oxygen equivalent to chlorin	0.110
	99.656

This well is located quite close to the Rio Grande and on the north side of the river. The river water at this point in its course carries 8.12 grains mineral matter per gallon.

Analysis of Brown Artesian Water; Depth of Well 750 Feet. Mineral Matter Held in Solution 104.3 Grains per Imperial Gallon

	Percent
Silicic acid	5.167
Sulfuric acid	0.196
Carbonic acid	36.923
Chlorin	0.434
Calcic oxid	0.563
Magnesic oxid	0.179
Potassic oxid	0.456
Sodic oxid	51.766
Ferric and alum. oxid	0.170
Manganic oxid (br)	0.146
Ignition	4.267
	100.276
Oxygen equivalent to chlorin	0.098
Total	100.178

These analyses have been published before with many others. They serve, however, just as well as any others, to show the characters of these three waters, the original water supplied to the valley, the white acid artesian waters that occur along the Rio Grande on the north side and south and west of the river, and the alkaline, usually brown water, north of the Rio Grande. These differences are evident even on a casual examination of these statements. In the river and white artesian waters there is a decided preponderance of acids, with lime and magnesia abundant in the mineral matter of the river water. These two bases recede in the white artesian water but the preponderance of acids remains pronounced, while in the alkaline or brown artesian waters these two bases and the silicic acid have disappeared to a very large extent, whereas sodium and carbonic acid have become almost the exclusive constituents.

We have intimated, though we have not formally expressed the view, that the white acid artesian water is really the mountain or river water, protected from deep-seated changes by the drainage from the southern end of the valley, which is no more than sufficient to regulate the water level in that section of the valley. It has also been stated that there are large springs and springy areas from which water of this same character is constantly flowing. In this section we have ground-waters of the usual character for a country whose soil is an "alkali" one; i. e. waters whose mineral contents consist essentially of sulfates of lime, magnesia and soda. These conditions are not the prevailing ones in the section north of the Rio Grande, where we have seen from the analyses of water that there is a radical change, both in the relative and absolute quantities of the salts present, and a most radical change in their character. A natural inference would be that the writer may have, for the purposes of his thesis, put favorable contrasts to the front while the facts presented in a fuller series might not show such to be the case. This is not true; the intermediate facts in the series are in perfect harmony with the extremes. To meet the misgivings that the facts may be considered by many to justify, I will add an analysis of an alkali collected on a desert-claim in this northern section. I do not think it possible to find such an alkali in the southern section, where we find the so-called white alkalis only, sometimes with an inexplicably large amount of calcic chlorid.

Analysis of Alkali from Desert-Claim, Northern Section of Valley

	Percent
Calcic sulfate	1.489
Magnesic sulfate	0.367
Potassic sulfate	2.874
Sodic sulfate	26.162
Sodic carbonate	40.368
Sodic chlorid	20.928
Sodic phosphate	0.959
Sodic silicate	4.271
Ferric and Alum. oxids	0.082
Manganic oxid	0.202
Excess sodic oxid	2.288
	100.000

This is without doubt the result of the evaporation of an artesian water and the reactions with the soil salts during the process.

Drain-waters and those from shallow wells show the same characteristics. A drain-water and that from a well only 15 feet deep show about 20 percent of the total solids to be sodic carbonate.

We have now stated that we offer the drainage of the southern section of the valley as the explanation for the maintenance of the similarity between the composition of the artesian and the river or mountain waters. We now propose the lack of drainage and concentration by evaporation with the concurrent reactions between the soil and the mineral constituents of the water as the factors that determine the composition of the alkaline waters. In the southern section only small changes have taken place for the simple reason that the water is in motion through sands or soil particles identical in composition with the rocks of its drainage surface, and the concentration of the solution remains approximately the same. In the northern section these factors are reversed; there is no general drainage out of the area, and the concentration of the solution has not remained the same. The reactions between the mineral contents of the water and the rock particles are very different. The sulfates and chlorids, together with the silicic acid, are removed. The calcic, magnesic and potassic salts are removed by precipitation or absorption, while the sodic carbonate remains in solution even when the concentration has increased its relative quantity perhaps 125-fold, as the analysis of the brown water roughly indicates. This statement of the case is nothing more than one of facts observed in ordinary soils. The sulfates and chlorids are retained quite largely while the corbonates go very freely into the drain-waters.

The mineral matters held in solution by the river waters flowing into the valley consist of silicic acid up to more than 40 percent of their total weight. In the case of the Poudre water, this silicic acid is probably largely removed as a calcic silicate. I have met with marls underlying our soils so rich in soluble

silicates that it would gelatinize on treatment with hydrochloric acid. The conditions in the San Luis Valley are different and the probability is that the silicic acid is removed as such by deposition on the soil particles in a manner similar to the cementing silica between the sand grains in the formation of quartzite, or in the formation of agatized wood. These waters are evaporated at the rate of from 30 to 36 inches per annum from the surface of these lands, or would be, provided they were constantly supplied with the necessary water; the sodic carbonate would remain in solution, the other constituents would be very largely or wholly thrown out of solution. These are the conditions indicated by the drain-waters and well-waters of this section, whether deep or shallow.

We have stated that among the changes is the removal of the silicic acid by precipitation on the surface of the soil or rock particles, and it is possible that this is the case to such an extent that it may account for the hardening of some of these soils. If this be the case, the relation between the alkali water and the hardening of the soil is direct and intimate.

We have attempted to find out whether any facts substantiate this view; if so, it will not only help in explaining the deportment of the soil but also in supporting the view expressed in regard to the origin of these alkaline, artesian waters. Referring to the soils we have the following facts: Sodic carbonate will cause some soils, at least, to harden; gypsum counteracts this, but in our case it failed. Plants may develop short roots but not distorted ones, where the water-plane is too high for the full development of the roots. Here we have distorted roots and the soil, when removed and packed in a sack, becomes very hard. The amount of sodic carbonate found on analysis was only about one-quarter of the minimum found to be injurious to plants, but we have no definite data as to how little sodic carbonate may produce a hardening or caking of the soil. The only data that we have indicates that the addition of an amount no greater than we found in this soil may produce a considerable degree of caking. This soil, in its natural position was not caked, it was too far below the surface, but the alfalfa roots did not penetrate it so the distorted roots were caused by some other factor. These were the specific facts, pro and con, that confronted us.

In order to test the question of the presence of hydrated silicic acid which might, on exposure to air and drying, serve to cement the particles together, we treated fresh samples of the soil, some with dilute potassic hydrate, and one with water. One sample was treated with a solution of potassic hydrate of 10 grams, and one with a solution of 20 grams to the litre, while a third one was treated with twice its own weight of distilled water. The samples of soil were treated as they were removed from the ground and were not allowed to dry.

The distilled water dissolved 0.008 percent. Ten grams of

potassic hydrate to the litre dissolved 0.229 percent; twenty grams of potassic hydrate to the litre dissolved 0.432 percent. The silica was weighed as SiO_2 but it undoubtedly existed in the soil as a hydrated acid. Weak solutions of potassic hydrate were used because it is known that stronger solutions will attack, even in the cold, chalcedonic forms of silica. The fact that soluble forms of silicic acid are present stands out plainly; even distilled water took up a noticeable quantity, 0.008 percent of SiO_2 calculated on the dry soil, while the amount dissolved by the two potassic hydrate solutions was proportional to the strength of the solutions. The soil was put into the solutions in the field and the silica determinations were completed eleven days later. I am aware that objections may be made to the interpretation that this silicic acid existed as free, hydrated, silicic acid in the soil, but it is a more reasonable assumption than any other that can be made in the case. The solution of 20 grams to the litre is too weak to attack the silicates in so short a time and to such an extent.

The amount of silicic acid, H_2SiO_3, which was removed by the stronger of the two solutions is very considerable. The sample taken represented six inches of the soil. Assuming that such a layer weighed 2,000,000 pounds per acre, we have about 5½ tons silicic acid soluble in such a solution per acre.

Is the supply furnished by the mountain water used in irrigating and the ground-water adequate to account for this? The only answer that we can offer to this is a consideration of the rate of accumulation, based on the amount of water evaporated from the surface of this land. If the power of soils to remove silicic acid from solutions, such as the mountain waters, has been determined, it has escaped my attention; but if the water is evaporated at the temperatures prevailing at the surface of these soils, the silicic acid would certainly be left. The evaporation from a free water-surface in this section has been given to me as 61 inches annually. This is about twice as great as it is from a soil surface, so we may assume 36 inches per annum as the amount of this evaporation. On the basis of these data and the silicic acid content of the Rio Grande water, it would be possible to have this much silicic acid deposited from this source alone in just a trifle over two years. The alfalfa was four years old and the conditions had existed at least this long, provided this is really the cause of the distorted roots.

These facts strengthen the view here intimated and elsewhere expressed, that the alkaline water of this area owes its existence to the lack of drainage and its character to concentration by evaporation and the elimination of silicic acid, lime and magnesian salts.

If silicic acid be the cause of the hardening of the soil, it will explain the failure of gypsum to ameliorate the condition.

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The Colorado Experiment Station

AGRICULTURAL DIVISION

GRASSHOPPER CONTROL IN COLORADO

C. L. Corkins
Deputy State Entomologist



Mixing Ammunition at the Schubert Camp

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GRASSHOPPER CONTROL IN COLORADO

By C. L. Corkins
Deputy State Entomologist

Grasshoppers are the most destructive insect pest of cereal and forage crops in Colorado. The average yearly potential loss, if no control measures were taken, is fully $500,000. This figure does not seem excessive in the light of a conservative crop value of one hundred millions of dollars per annum, which sets the 'hoppers toll at one-half of one per cent. During an exceedingly bad locust year, the possible devastation may reach several millions of dollars.

Grasshoppers in Colorado are just as permanent as agriculture. Certain species have adjusted themselves to our cultural methods and thrive better under our system of farming than under natural conditions. Other species will continue to abound on our non-tillable pasture and waste lands, destroying feed over large grazing areas or even becoming so numerous that they will migrate into cultivated crops. In the face of these facts, all our farmers should consider a knowledge of grasshopper control fundamental to successful farming.

We recognize four factors which make for successful control of a grasshopper outbreak.

1—Knowledge of the life history and habits of the species concerned.

2—Knowledge of proper control measures and the opportune time to apply them.

3—Business-like organization with competent leadership embracing the co-operation of all farmers, enforceable where necessary.

4—Adequate funds, efficiently managed, with which to carry on the campaign.

The information herein contained is an enlargement on these points.

FIVE DESTRUCTIVE SPECIES OF GRASSHOPPERS

The life history, habits and control of five of our most destructive locusts in Colorado are alike in so many respects that they may be treated largely in one discussion. The essential differences in their habits are pointed out in the following list:

Mr. Corkins' salary and expenses while securing the data and writing this bulletin were paid from budget of the State Entomologist of Colorado.

Two-Striped Locust (*Melanoplus bivittatus* Say).—The history of this grasshopper over a long period of years undoubtedly proves it to be the most destructive species known. It has adapted itself admirably to agricultural practices, having selected the alfalfa fields of our irrigated valleys as favorite breeding grounds. Here its eggs are seldom disturbed and the succulent alfalfa is its favorite food, making optimum conditions for enormous increase. Eggs are also deposited freely along ditch banks and fence rows.



Female Two-Striped Locust. Enlarged ½. Original

From alfalfa fields, the Two-Striped Locust will move into other crops, especially after the first cutting of hay is removed. No crop is immune from attack. Orchards are sometimes completely defoliated, the fruit eaten and the bark of the terminal growth devoured as a last resort. The silk of corn is a favorite food, tho the entire plant may be destroyed. Other cereals may be completely devastated or, if in the head, the kernels eaten or clipped. This species is also commonly destructive to vegetable gardens and field root-crops.



Male Two-Striped Locust. Enlarged ½. Original

Epidemics of the Two-Striped Locust are usually restricted to certain fields or areas. Because of its robust body with relatively small wings inadequate to carry the insect far in flight, widespread migration never occurs. It is only able to move from field to field, marching or jumping combined with some use of the wings while in the air. For this reason one farmer can, with fair success, protect his crops tho his neighbors neglect to kill their 'hoppers.

The nymphs or baby 'hoppers begin to hatch in May, and it is characteristic of this species that the duration of hatching is long extended so that small ones may be found after adults are numerous. Adults may be seen by the middle of June but are not numerous until later.

The distribution is general over all the agricultural areas of the State, epidemics occurring in both the higher mountain valleys and in the irrigated sections of the eastern plains.

Lesser Migratory Locust (*Melanoplus atlanis* Riley).—This grasshopper is a more general feeder than the Two-Striped Locust, being found in abundance on the dry prairie, the uplands, and the valleys as well. However, its greatest damage is done to native pastures and dryland crops. When severely epidemic, it has not been known to refuse any cultivated plant and will even gnaw dry wood such as fence posts and the handles of farm tools.



The poison is slow in action, dead 'hoppers being found under weeds and rubbish after from two to five days. (State Entomologist s Report, Circular 36.)

Epidemics of this species are often quite wide-spread. Migrations for short distances are also possible, especially when food becomes scarce or tough. For this reason, success in control measures depends upon unity of action by all concerned. Persistent effort upon the part of a few farmers is not without good returns, but is usually very discouraging.

These 'hoppers hatch about the time the spring crops are well up. Usually the majority of the eggs hatch at about the same time, so that control measures should be entered upon before the adults appear. This is especially important when the hoppers are hatching in native pastures, along roadsides, ditch banks or other restricted areas. They should be destroyed before spreading from the smaller breeding grounds to the larger cropped areas.

This is undoubtedly the most generally distributed species of locusts in Colorado. "It may almost be said to occur everywhere up to an altitude of 8,500 feet." (Gillette).

Red-Legged Locust (*Melanoplus femur-rubrum* DeGeer).—This species is found under much the same conditions as the Lesser Migratory Locust. In an epidemic, sometimes the one species predominates and sometimes the other. The Red-Legged Locust differs in habits from the Lesser Migratory Locust mainly in the following ways:

1—It seldom migrates, tho it may move from field to field.

2—Epidemics are usually local.

3—It is commonly more abundant in cultivated fields than in native pastures or uplands.

Differential Locust (*Melanoplus differentialis* Uhl).—In food and migratory habits this species closely resembles the Two-Striped Locust, and is often found interspersed with it. However, its distribution is not so general, being confined to the irrigated valleys of the lower altitudes.



Male Long-Winged Locust of the Plains. Enlarged ½. Original

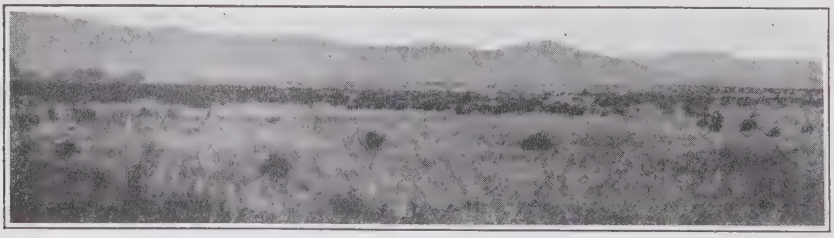
The Long-Winged Locust of the Plains (*Dissosteira longipennis* Thomas). — The Long-Winged Locust of the plains becomes epidemic but very seldom. An outbreak affecting El Paso, Lincoln, Pueblo and Crowley Counties in 1921 was the first of any size since the early nineties. Yet, this infestation, which was some 43 miles long, marks this insect as a serious pest when abundant.

This species is confined to the eastern plains of Colorado, breeding on the native pasture lands. It is indifferent to cultivated plants until it becomes very numerous, at which time it shows little or no preference to them over the native buffalo and grama grasses.



Female Long-Winged Locust of the Plains. Enlarged ½. Original

Characteristic of this locust is its migratory habits. Nymphs march in solid armies, hundreds to the square yard; when they become adults and have their wings they take to the air with remarkable ease, and with the aid of the wind may fly long distances. It is therefore imperative to check an outbreak before these 'hoppers reach the adult stage.



Destruction wrought to wheat field by hoppers. Original

LIFE HISTORY

Egg Stage.—Eggs are deposited by mature females, beginning in abundance about the middle of August. Oviposition, or egg-laying, is then continued until cold weather prevents grasshopper activity. For egg laying, a rather firm, yet not caked or baked soil, free from stones and roots, is preferred. Hence, cultivated fields are little used. Roadsides, ditch banks, pastures of alfalfa, virgin land and neglected fields are more likely to be selected. However, where 'hoppers are unusually abundant, they will also fill the soil of cultivated fields with egg pods.



Egg Pods of the Two-Striped Locust. Pod on Right With Outer Surface Removed. Enlarged 2 Times. Original

Upon choosing a suitable place for oviposition, the female will, with muscular action, work her abdomen into the ground with the aid of horny, sharp projections at its tip. Unless some hard substance is encountered, the abdomen will be inserted its complete distended length, which may be as much as two inches. At the bottom of the hole thus made, the eggs are deposited one by one, pasted together and encased in a frothy, glue-like substance which hardens. The individual eggs are somewhat crescent-shaped, tapering at both ends, cream-white in color and about one-fifth of an inch long. When oviposition is completed, the result is a mass of regularly placed eggs in a slightly curved pod from three-fourths to one and a quarter inches long, the encasement being practically weather proof so long as it remains in the ground. The number of eggs laid in each pod and the number of pods will vary with the individual as well as with the species concerned. There are from two to three pods of fifteen to fifty eggs each per season, making a total of thirty to one hundred and fifty eggs for each female.

None of the adults live over winter to the next spring. All of the five species named pass the winter in the egg stage.

Nymph Stage.—At about the time crops are well up, the nymphs or baby 'hoppers hatch, force themselves out of the egg pod and to the surface of the ground. These nymphs, except for size, the lack of fully

developed wings and a large head in proportion to the body, resemble the adult grasshopper. Upon feeding and growth, they are literally forced to shed their "skin" in order to accommodate the increase in size. To effect this process, which is termed molting, the 'hopper will crawl upon vegetation or some other object and cling with its head downward. The skin then splits over the head and along the back. By muscular effort the 'hopper works its way out, emerging with a larger, yet paler and softer coating. Upon exposure to the air, the new skin becomes hardened and darkened. The cast-off skin remains attached quite firmly to the object upon which the grasshopper was clinging. Farmers seeing these in large numbers will often think them dead 'hoppers and believe that some disease has come to the rescue.

Usually after the fifth molt, the adult stage is reached, in which case the 'hoppers have fully developed wings and are sexually mature. The nymphal period varies from 45 to 80 days, depending upon the species in question, climate, locality, and other minor factors.

Adult Stage.—The adults, some of which appear about the middle of June and are abundant in July, feed voraciously for a period of from two to five weeks. During this time, mating or copulation takes place and the eggs are formed in the bodies of the females. Migration in some species, notably *Melanoplus atlanis* and *Dissosteira longipennis*, may occur during this period.

When the eggs are ready for laying, the females will leave the grain fields in search of suitable places for oviposition, followed somewhat by the males. After depositing one pod of eggs, the females may return to the feeding grounds. Such a movement is not termed migration. This completes the life cycle, which covers a year's time and makes one generation per season.

HABITS

Migratory and food habits have been discussed under each species since they vary somewhat.

Time of Feeding.—The period of most active feeding is during the morning, commencing as soon as the 'hoppers are thoroughly warmed up by the sun and lasting for about two hours. In the lower altitudes of the State this normally begins about 8:00 a. m. and in the higher altitudes about 8:30 a. m., reaching the peak shortly before noon and then rapidly declining. A second feeding begins in the afternoon, about four or five o'clock, but is neither so general nor so intensive as the previous one. During cold or damp weather, the 'hoppers, especially the young, will bunch together in masses in the more open places in the field, upon rocks, clods, or the dryer spots, and do not feed.

Nature of the Injury.—Where the grasshoppers are very abundant, small grains are often eaten to the ground before they have had a chance to gain a good start. Injury on larger plants may vary from partial to complete defoliation, leaving only the tough stalk standing. Even partial defoliation is a very serious handicap to the grain. A large part of the plant food is gained from the air thru the surface of the leaves. Hence, a loss of leaf surface greatly reduces both the quantity and quality of grains.

Especially during a dry season when succulent food is scarce, severe damage may be done by a limited number of 'hoppers upon the heads of grain. Kernels of wheat and barley may be eaten out, or even the heads cut off completely. Oat kernels are often clipped off one by one and dropped untouched to the ground. Prevention of fertilization of corn is often accomplished by the eating of the silk. Such injuries are not apt to be encountered except in the dry-farming regions of the State.

Roosting.—After the evening feeding, the 'hoppers crawl up on vegetation, fence posts, buildings or other objects, with head uppermost, and roost during the night. This is done, presumably, to avoid the dampness of the ground. Nymphs and adults alike participate in this roosting habit.

ARTIFICIAL CONTROL MEASURES

Artificial control measures are those employed by man to check damage. These are largely of two kinds, remedies and prevention.

Remedies—Poison Bran Mash

Of the artificial methods of control, the use of poison bran mash has been proved to be the most practical and efficient. It is now adopted as standard in the United States and Canada. The original Kansas bait has been the basis of many later modifications, so that at the present time, several different formulae are used. Four are here given which will best meet different Colorado conditions.

Formula No. 1

Bran (free of shorts)	100 pounds
Crude white arsenic (90 to 98% As_2O_3)	5 pounds
Salt	5 pounds
Stock molasses (or any cheap grade)	2 gallons
Lemons (finely ground)	2 dozen
Water	9 to 11 gallons

Formula No. 2

Bran (free of shorts)	100 pounds
Crude white arsenic (90 to 98% As_2O_3)	5 pounds
Salt	5 pounds
Stock molasses (or any cheap grade)	2 gallons
Amyl acetate, or banana oil (Tech. No. 1)	3 ounces
Water	9 to 11 gallons

Colorado Grasshopper Bait No. 12

Bran (free of shorts)	100 pounds
Sodium arsenite (8 pounds As_2O_3 per gallon)	1 pint*
Salt	5 pounds
Sugar beet refuse molasses (or any cheap grade)	2 gallons
Amyl acetate, or banana oil (Tech. No. 1)	3 ounces
Water	9 to 11 gallons

Colorado Grasshopper Bait No. 15

Sawdust	2 bushels
Bran (free of shorts)	50 pounds
Sodium arsenite (8 pounds As_2O_3 per gallon)	1 pint*
Salt	5 pounds
Sugar beet refuse molasses	2 gallons
Amyl acetate, or banana oil (Tech. No. 1)	3 ounces
Water	10 to 12 gallons

*Where killing within 24 to 48 hours is desired, use one quart.

Formula No. 1 is rapidly passing out of usage, tho it has been the standard for a number of years. Its only advantage is that lemons are usually easily obtainable, tho they are very expensive, while banana oil may be difficult to procure in a short time.

Formula No. 2 was developed by the Department of Entomology of Montana State College in 1919. The banana oil is at least equal to citrus fruits as an attracting agent and much cheaper and easier to handle. Many of our western states and provinces of Canada have adopted this formula in the past two years. The writer has given it extensive trials under severe epidemic conditions in North Dakota one season and in Colorado two years, with equally as good results as with Formula No. 1.

In using banana oil the following cautions should be borne in mind:

1—Procure only pure banana oil which is recommended by College authorities. Grades lower than Technical No. 1, which contain adulterants, cannot be used.

2—Banana oil used in excess of the amount given in the formula acts as a repellant. Be sure to accurately measure the exact quantity.

Colorado Formula No. 12 was developed by the Colorado Experiment Station with the idea of obtaining a better killing agent than crude white arsenic. Due to the fact that the arsenic is very heavy and but slightly soluble in cold water, poor mixing very often results. The sodium arsenite used in this formula is entirely soluble in cold water, which means that all particles of water carry exactly the same amount of poison, and that every flake of bran which is moistened is also poisoned. From the standpoint of mixing, it is a "fool proof" killing agent. It is also somewhat cheaper and easier to handle than white arsenic and is fully as efficient.

At the present time, there is still the disadvantage of the inaccessibility of sodium arsenite on the market. The College is doing all possible to remedy this situation and will gladly help the farmers to secure this chemical.



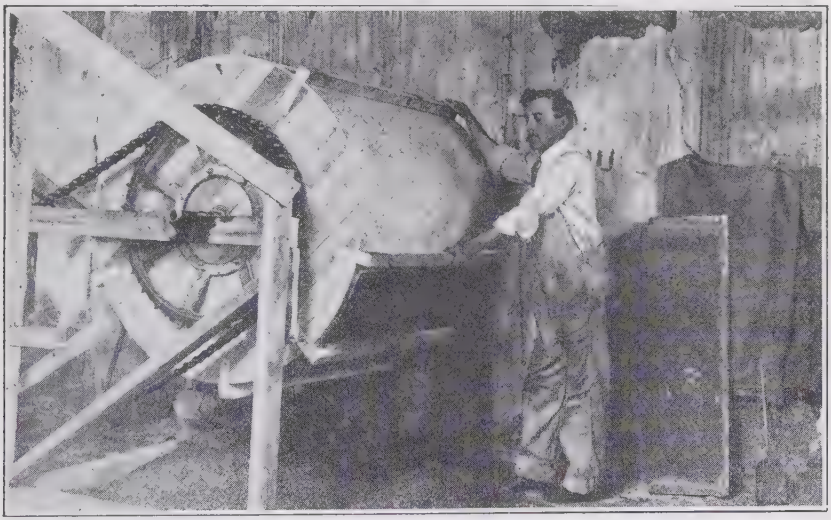
Trucking in bran and other poison supplies for a 60-ton campaign. Original

Colorado Formula No. 15 is given for use principally on pasture lands in the foothills of the State where sawdust may be easily obtained. It will cheapen the use of the bait for these lands and help to make it more practical, from the standpoint of cost, for areas of 'ow production value per acre.

The Bran.—Bran free from shorts should always be used. The gluten in shorts will cause the bran to ball up and stick together upon broadcasting. Most millers of the State have shown a fine spirit of co-operation by running bran free from shorts for this purpose, tho they seldom make it as a commercial practice.

Substitutes for Crude White Arsenic.—In place of crude white arsenic for each hundred pounds of bran, may be substituted four pounds of refined white arsenic or three pounds of paris green. The objection to them is that they are more expensive and no more effective.

The Water.—The amount of water needed will vary with the physical quality of the bran. The coarser the bran, the less the water requirement. The mash should not be sloppy nor even wet enough to stick together. Ten gallons is usually sufficient water for Colorado bran.



Sumpter mixing machine used to mix paris green bran mash, Center, Colorado, 1916. Time required to prepare, mix and sack 100 pounds, dry weight, of the bran mash, eight minutes. (Colorado Experiment Station Bulletin No. 233.)

Mixing the Mash.—Success in using the poison bran mash depends so largely upon the proper mixing that too much stress cannot be laid upon closely following directions, as simple as they are.

Mixing may be accomplished either by hand or by a power machine.

Except for large outbreaks, hand mixing is by far the most practical and will be discussed here.

A building with a tight board or cement floor makes an ideal mixing station. In lieu of this, mixing may be done outdoors on large tarpaulins.

Five hundred pounds of bran may be mixed at one time. The water, molasses, ground lemons (or the banana oil) and salt are all vigorously stirred in a tank or some other adequate receptacle. The poisoning agent is then added and the whole again agitated. If arsenic has been used, great care must be exercised to make sure that it is evenly suspended in the water and none has settled to the bottom. The soup is poured over the bran slowly and mixed in by means of beet forks, shovels or rakes. Five or six mixings from one pile into another will usually be sufficient. If the mash is left to stand, it may be kept without injury for one or two days by covering with wet sacks.

Application.—After mixing, 100 pounds of mash figured on the dry basis, will cover from twelve to twenty acres. The tendency is to spread too much rather than too little. A thin sprinkling, scattered evenly over most of the ground, is desired.

The mash may be applied broadcast by hand from the rear of wagons, buckboards, or even automobiles. It will scatter best if thrown crosswise to the wind. More efficient spreading may be accomplished by the use of a large end-gate seeder. The mash must be fed into the hopper a handful at a time, else choking results. Special apparatus built upon the same plan as an end-gate seeder, but with a larger throwing disc and a faster gearing, may be constructed from cast-off machinery by the ingenious farmer. Such has been used with remarkable success.



Hand spreading demonstration. (Colorado Experiment Station Bulletin No. 233.) Jones

The time of feeding is the safe guide for the time of application. **Poisoning should, therefore, be done in the morning only, from eight o'clock until noon, or shortly thereafter.** Mash put out earlier in the morning will be dried up and caked together by the sun before the 'hoppers are active. Not only from the standpoint of a lighter feeding, afternoon poisoning often fails because of sudden unforeseen showers.

The number of applications will vary. One is seldom sufficient. Two or three are usually necessary.

When to Begin Poisoning.—In this combat, procrastination is very often the locust's victory. The first hard and fast rule of the game is to prevent 'hoppers from gaining access to the small grain fields, especially if the plants are tall and thick enough to completely shade the ground. Poisoning in heavy wheat or oats is very discouraging. It should be done before the nymphs leave their hatching beds on waste lands, ditch banks and roadsides.

In the case of an infestation of the Two-Striped or the Differential Locust, where they have hatched in alfalfa fields, it is usually wise to leave poisoning operations until after the hay is cut and raked. Very little damage is likely to be done to the first cutting. Neither are they apt to migrate from alfalfa fields to other crops. One exception to this is the case where small grains are on the border of the alfalfa, in which event a swath of hay about two rods wide should be kept mowed down and occasionally poisoned.

Cost.—The cost varies with so many factors that it is difficult to get accurate figures. Computing on the basis of the average of several large campaigns, it will approximate about 40 to 50 cents per acre for both material and labor.

On native pasture lands where one application of Colorado Formula No. 15 is commonly sufficient, the cost, including labor, will average about 20 cents per acre.



Part of 553 hogs grazing on alfalfa after paris green bran mash had been sown to control grasshoppers at the rate of eight pounds per acre. No animals were poisoned. C. R. Jones. (Colorado Experiment Station Bulletin No. 233.)

Stock Poisoning.—If the bran mash is mixed and spread according to directions, there is no danger of poisoning either stock or fowls. In the writer's experience in large campaigns in three different states, he has not known of the loss of any animals except from carelessness around the mixing vats. The only caution is to exercise great care in keeping all mixing utensils away from children and domestic animals.

Spraying with Insecticides

Spraying with insecticides usually does not give much relief. Of these methods, spraying with kerosene emulsion along roadsides or on other waste lands soon after the 'hoppers have hatched and before they begin moving to the fields, probably gives the most satisfactory results.

It should be stated, in order to avoid unnecessary expense, that spraying with arsenicals, such as paris green or arsenate of lead, has almost invariably proved a failure.

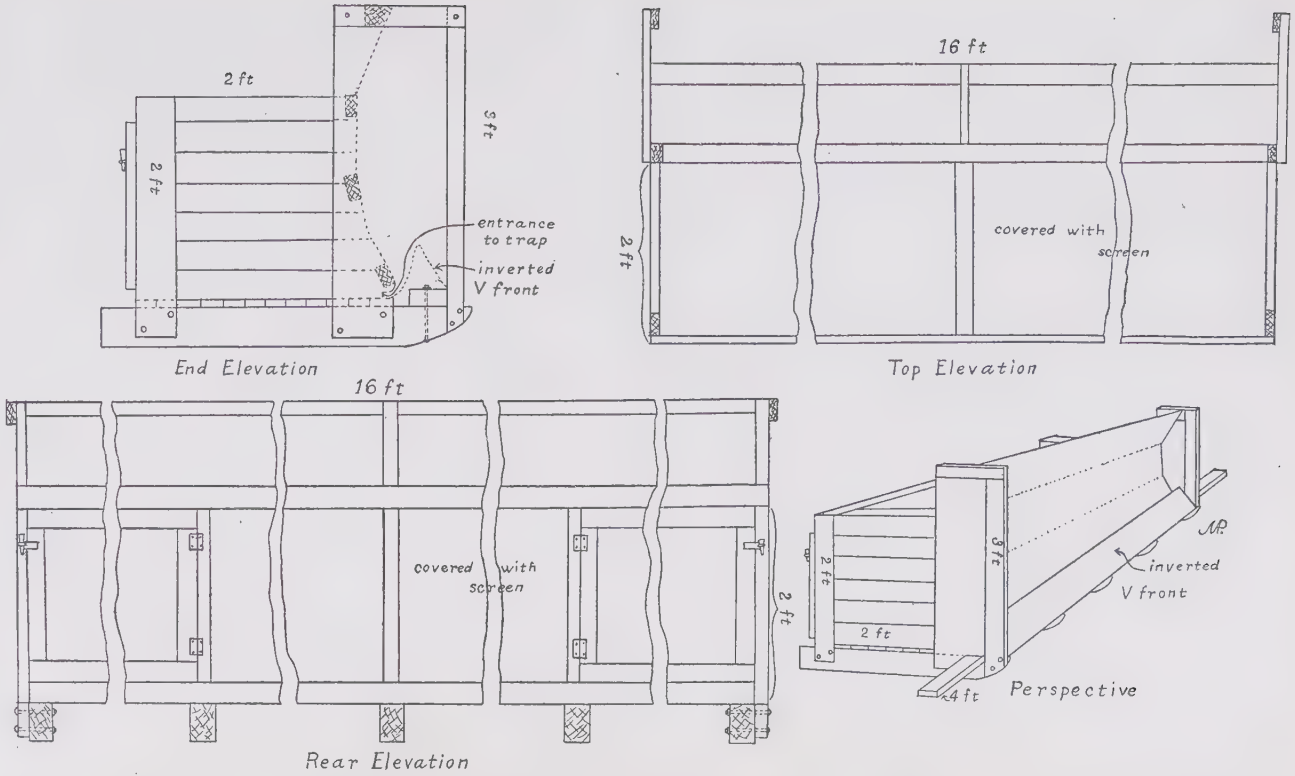
Hopper Dozers*

The use of the "hopper dozer" is so well known that it needs but passing mention. Two variations in the common method of locomotion might well be mentioned. One is the mounting of the dozer on the teeth of a bullrake, thus giving vertical adjustment for use in running over tall alfalfa or other fields. The other is a small, 12-foot dozer, detachably mounted on the front of a "flivver." Such an apparatus is very successful in the point of saving time. It should be used just before evening when the 'hoppers are still quite active or in the morning when they begin to move about.



A 'hopper dozer in action. One of the many machines that was used in the grasshopper campaign, 1916, San Luis Valley. (Colorado Experiment Station Bulletin No. 233.) Jones.

*For directions in construction and use of 'hopper dozers and catching machines, see "Grasshopper Control," Bulletin 233, Colorado Agricultural Experiment Station, by C. R. Jones.



A detailed diagram of a grasshopper catching machine. (Colorado Experiment Station Bulletin No. 233.) Jones

Grasshopper Catching Machine

The grasshopper catching machine, designed to catch live 'hoppers, was successfully used in Colorado in 1902. Similar machines have given good results in Utah, New Mexico, Montana, North Dakota and other states. These have two distinct advantages over the "hopper dozer," namely, they may be used on rough ground, and the hoppers may be saved, dried and used as winter chicken feed.

In the event that hoppers are used as chicken feed, they may be scooped into sacks, thus left for two days or until dead and then spread out to dry on a tarpaulin in the sun. Otherwise, they may be killed in the machine by spraying with kerosene.

PREVENTION

Methods discussed under this heading are designed to work along the lines of the old adage that "an ounce of prevention is worth a pound of cure." In the case of grasshopper control, this may not be literally true, yet some measures of prevention can well be employed. Where intensive agriculture is practiced, these methods are of the most value. They cannot be said to be practical where egg beds cover vast areas of waste land.

Of these measures, late fall or early spring plowing to the depth of six inches is most sure. It should be understood that this method works by burying eggs so deeply that the young 'hoppers cannot escape upon hatching. Therefore, shallow plowing or failure to turn the furrow under is ineffective. If the soil is sandy and light, it should be well packed after plowing to prevent the 'hoppers from working thru.

Thoroly discing the ground three ways, lengthwise, crosswise and cornerwise, in the fall has been effective in many cases. Such a procedure breaks up the egg pods, smashes or exposes the eggs to the elements or natural enemies. The greatest objection to it is that few farmers will do the work thoroly enough to get results.

NATURAL CONTROL

Insect Enemies.—It is very often the case that a season of heavy grasshopper damage is followed by a year of little or no injury. Such a phenomenon may be due to the fact that insect enemies have become so numerous as to hold the 'hoppers in check. Of these, a group of flies known as the Sarcophagids are perhaps the most important. They resemble the house fly somewhat in size and general appearance, tho some are larger. When numerous, these flies may be observed to dart at the 'hoppers as soon as they stir. They do this to deposit, either an egg or a living maggot. If an egg, it will soon hatch into a maggot which enters the body cavity and lives upon the internal organs. One maggot is sufficient to so devitalize a female 'hopper as to prevent egg laying. When fully grown, the maggot will leave its host and enter the ground for pupation. Their average life cycle is about three weeks, so that several generations a season are possible.

Among the insect enemies of grasshoppers are other parasitic flies, ground beetles, robber flies, blister beetles and wasps.

Locust Mite (*Trombidium locustarum*).—Closely related to the insect enemies is the Locust Mite. This mite, which is red in color, is often seen in great abundance attached to all parts of the 'hopper's body. However, the most seve e damage that the mite commonly does is to lessen vitality and occasionally distort the shape of the wings. The writer has observed migratory locusts that have flown for many miles while infested with as many as a half dozen of these mites with no apparent handicap. The farmer often hails the appearance of these parasites as the end of his troubles, only to be met with disappointment.



Grasshoppers killed by *Empusa grylli* Fres clinging to oat heads, Trinidad, 1916. (Colorado Experiment Station Bulletin 233.) Jones.

Fungous Disease. — There is a fungous disease (*Empusa grylli* Fres), which has been known to kill large numbers of locusts in Colorado and other states. However, its appearance is very erratic, the good done often localized and the period of heavy killing very short.

The first characteristic symptom of this disease is the tendency of the infected 'hopper to climb up the stem of some vegetation, attach itself head uppermost in a death-like grip and with the hind legs akimbo. The body soon becomes somewhat softened and distended, due to the growth of the fungus. With death, the 'hopper blackens and remains attached in the characteristic position.

Attempts at artificial spreading of this disease have given no satisfactory results.

Birds.—Many birds have more or less of an insectivorous habit. Even those birds that we think of as seed or vegetable eating, or as scavengers and birds of prey, will, in the presence of an abundance of insect food, break away from their normal habits and take that which is at hand in abundance. Thus, in the history of large grasshopper outbreaks, many other than the commonly insectivorous birds have been noted as accomplishing much good. However, it should be emphasized that birds are of the greatest importance as constant, rather than sporadic consumers of insect life, and as such do much to maintain the balance in nature.



Chickens in the field used as a method of control for grasshoppers, 1916, San Luis Valley. They did very efficient work immediately around the portable coop, which was moved every other day. (Colorado Experiment Station Bulletin 233.) Jones.

ORGANIZATION FOR CONTROL MEASURES

By taking advantage of the Amended Pest Law*, Colorado farmers are fortunate in being able to have a very efficient basis for grasshopper control. Without such a law, the more progressive farmers usually take all the burden and suffer reinfestation from their less progressive neighbors. To make control measures successful, it is necessary to have volunteer co-operation of the majority of the people interested and compulsory action of the others, including the non-resident land owner. The office of the State Entomologist will gladly co-operate with the various communities infested with grasshoppers in effecting a working organization.



All day picnic organization meeting for grasshopper control. Original

*See "Colorado's Amended Pest Law," State Entomologist Circular No. 32.

FINANCING A GRASSHOPPER CAMPAIGN

The matter of adequately and efficiently financing a grasshopper campaign so very often depends upon local conditions that it is impossible to make any specific recommendations. Considerable experience with this problem suggests two principles which seem fundamental and may be of some service:

First—In an extensive grasshopper outbreak, it is economically fair and just that all of the residents of that territory share some of the financial burden. Since farming is the basis of all industry, it is reasonable to expect that heavy crop losses over a large area will also seriously affect business and professional life closely associated therewith. For this reason, county officials should feel morally and legally justified, as an emergency measure, to use funds secured from general taxation for the alleviation of widespread insect depredations.

Second—Each and every farmer benefited by outside financial assistance should also personally share at that time a goodly portion of the expense of poisoning operations on his own premises. If the land owner is furnished all of the poisoning supplies by the county and feels no direct connection between it and his bank account, very often waste results. But, if he has just paid half of the cost out of his own pocket, there will be a potent incentive to use these materials more economically and efficiently.

Bulletin 288 October, 1923

The
Colorado Experiment Station
AGRICULTURAL DIVISION

THE PIT SILO

By JOHN W. SJOGREN
Associate Agronomist



Figure 1.—Pit silos on the Plains Substation Farm at Cheyenne Wells.

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THE PIT SILO

By John W. Sjogren

Where the soil formation will permit and where the underground water is not too close to the surface, the pit silo is a very practical type to construct. The purpose of this bulletin is to give information necessary in the construction of a pit silo.

Advantages of the Pit Silo.—The pit silo has some advantages over other types.

First:—Pit silos cost less to construct.
Second:—There is no trouble from feeding frozen ensilage.
Third:—Less power is required in operating the ensilage cutter, because it is not necessary to raise the ensilage to any considerable height.

Disadvantages of the Pit Silo. The pit silo cannot be economically constructed in regions where the soil has a tendency to cave in. If the soil will not remain in an upright position, it will be necessary to construct a heavy retaining wall, and this will require almost as much material as building a silo above ground. The ensilage is more difficult to remove from the pit silo than from the above-ground type. This objection can be largely overcome by constructing a good hoisting derrick. Another objection is the danger of the formation of a poisonous gas called carbon dioxide on the surface of the ensilage at filling time. This gas continues to form for ten days or two weeks, after which time very little is formed. No one should enter the pit at filling time, until after the ensilage cutter has been operated a few minutes. The falling ensilage will drive out the gas from the bottom of the silo.

Constructing the Retaining Wall.—After a desirable location has been decided upon, the ground should be marked off. A simple device for this purpose can be constructed as indicated in Figure 2 from a piece of 2″x4″ about fifteen inches longer than one-half the diameter of the silo. In one end, bore a hole and fasten by means of a spike or bolt to a stake driven in the ground where the center of the silo will come. Lay off and mark on this piece, the length A B which should be one-half the diameter of the silo. Nail a marker, which can be made from any piece of one-inch material, to the 2″x4″ at this point. Another marker should be placed at a distance of six inches from the first. A trench should then be dug between the two circles and as deep as can be conveniently dug with a space. A tiling spade will be better for this purpose than an ordinary spade. Care should be taken to keep the inside wall smooth.

This trench is then filled with concrete. A good mixture for this purpose is one part of cement, $2\frac{1}{2}$ parts of sand, and 5 parts of gravel. If bank-run gravel is used, 1 part of cement and 5 parts of bank-run gravel is equivalent to the above mixture. The purpose of this wall is to prevent the surface soil from caving in.

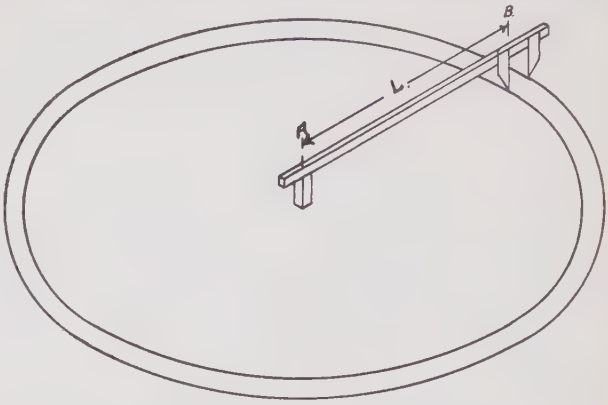


Figure 2.—Marking Off the Ground.

It is well to extend this wall three feet above the ground to prevent the danger of stock falling into the silo. The above-ground portion should be constructed before much excavating is done. The walls can be made of concrete or "adobe." If concrete is used, it should be of the same mixture as the retaining wall, but it is well to reinforce it with some good woven-wire fencing. The forms can be made of battens nailed to pieces of 2″x4″ driven into the ground every two or three feet. If "adobe" is used, the walls above the ground should be ten or twelve inches thick and plastered inside and outside with cement plaster.

Constructing the Wall.—After the concrete in the retaining wall has set properly, the soil should be removed to a depth of five or six

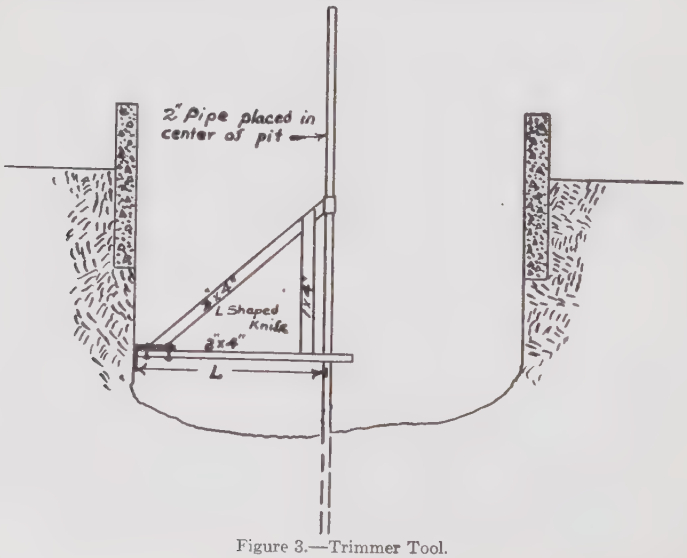


Figure 3.—Trimmer Tool.

feet below the retaining wall. Care should be taken to keep the wall smooth and plumb. Figure 3 shows a device for trimming the wall and keeping it plumb. It consists of an L-shaped knife attached to a 2″x4″. The distance from the center of the pipe to the knife should be one-half of the diameter of the pit, plus one inch to allow for the plaster. This device is held in place by means of a two-inch pipe, placed in the center of the silo. The hole for the pipe is made with a soil auger.

After the dirt has been removed, the walls should be given two or three coats of cement plaster, made by mixing one part of cement and two parts of clean sand. The sand and cement should be mixed thoroughly, then enough water added to make a good mortar. The coats of plaster can be put on as separate coats, or else plaster four or five yards, and then go over it with a second coat, before it has time to set. If the dirt wall is dry, it should be moistened with water in order to make the mortar stick to the walls better and to prevent the soil from absorbing the moisture from the plaster too rapidly. The plastered wall should be kept moist for several days while setting. After the plaster has set, it should be given a coat of cement wash, made by mixing one part of cement and one part of fine sand to a creamy con-

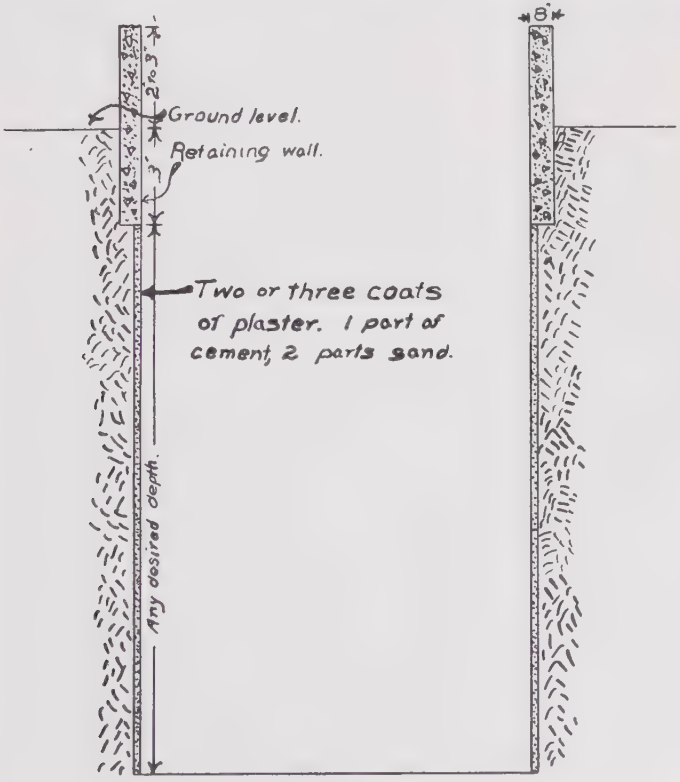


Figure 5.—Section Through Pit.

sistency. Another five or six feet of dirt is then removed and the walls plastered, as described above. This process is continued until the desired depth is reached. The bottom of the pit should not be plastered, as the dirt bottom is more desirable than a concrete one. Figure 5 shows a cross-section through the center of the pit.

Hoisting the Dirt.—There are several methods used in hoisting the dirt out of the pit. Figure 6 illustrates a method, where a common hay fork carrier is used. The rail is fastened to a 2″x8″, supported by

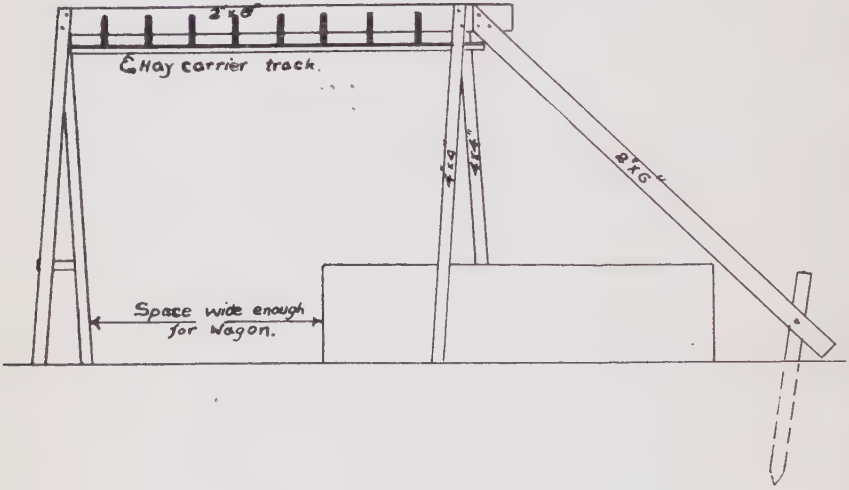


Figure 6.—Derrick For Hoisting Dirt.

tripods at each end. The 2″x8″ should extend beyond the pit far enough to allow a wagon to get between it and the tripod. The dirt is then hoisted, dumped into a wagon and hauled away. Another type of derrick is shown in Figure 1.

The container in which the dirt is hoisted can be made from a wooden oil barrel sawed in halves. The supports should be fastened below the center, as shown in Figure 7. This will make dumping easy. A square box properly braced, with a hinged bottom can also be used.

Removing the Ensilage.—The construction of an efficient hoist will reduce time and labor in removing the ensilage. Figure 1 illustrates a type of hoist that is used a great deal. The upright or mast may be made of a 4″x6″ piece or two 2″x8″ pieces. The top and bottom are made so that the crane can be turned and the upright should be securely fastened from the top by means of guy wires. A hand windlass may be placed on the upright or a set of pulleys may be used and the ensilage hoisted with a horse or team. A cart for hoisting ensilage can be made as illustrated in Figure 8. The cart is filled with ensilage and then hoisted to the top of the silo. The crane is then turned and the cart lowered to the ground and wheeled on planks to the feeding troughs.

Several companies manufacturing barn equipment make hoists which can be attached to an ordinary gas engine. By securing one of these, the gas engine can be used for hoisting ensilage providing it is three horse-power or larger.

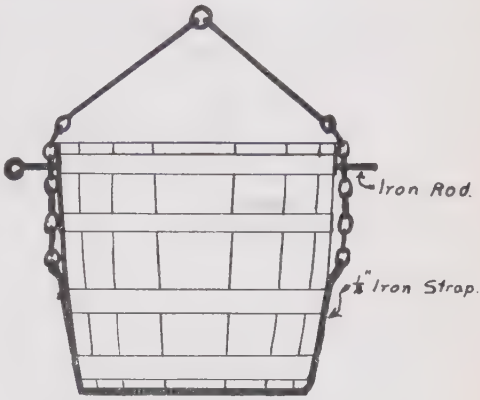


Figure 7.—Half-barrel For Hoisting Dirt

Size of the Silo.—The size of silo to construct depends upon the number of cattle to be fed and upon the length of the feeding season. In order to keep the ensilage fresh after feeding has begun, a depth of at least two inches should be removed daily. The diameter, therefore, depends upon the amount of the ensilage to be fed each day.

Table I shows the number of animals which should be fed from the silos of various diameters in order to remove two inches of ensilage daily, when various quantities are fed.

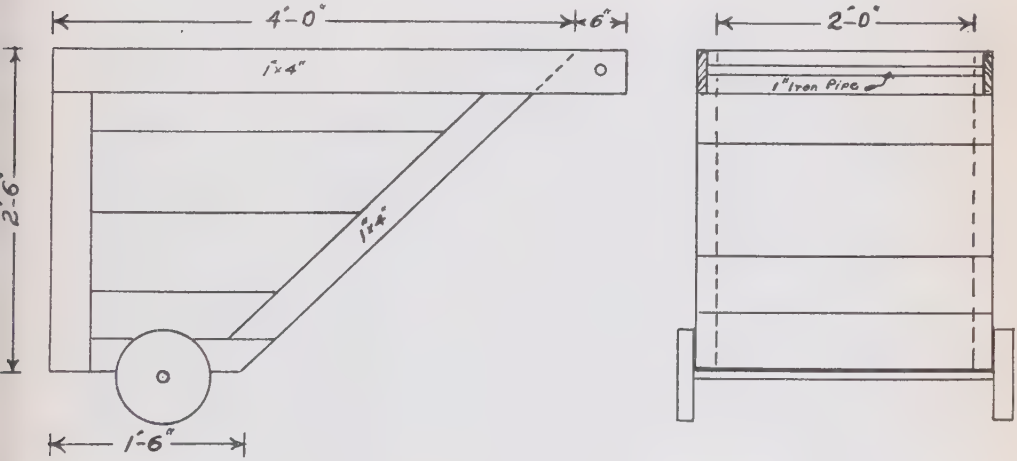


Figure 8.—Cart For Hoisting Silage.

The depth of the silo will depend upon the length of the feeding season. Table III gives the tonnage at various depths of different-sized silos.

TABLE I—Relation of Herd to Diameter of Silo

Diameter of Silo	Pounds Removed	NUMBER OF ANIMALS FEEDING VARIOUS QUANTITIES					
		40 Lb. Per Head	30 Lb. Per Head	25 Lb. Per Head	20 Lb. Per Head	15 Lb. Per Head	5 Lb. Per Head
10 Ft.	523	13	17	21	26	35	105
12 Ft.	754	19	25	30	38	38	151
14 Ft.	1,030	26	34	41	51	69	206
16 Ft.	1,340	33	44	54	67	88	268
20 Ft.	2,100	52	70	84	105	140	420

Materials Required.—Table II shows the amount of material needed for the retaining wall, six inches in thickness, and for the plastered wall, approximately one inch in thickness, for each foot in depth.

In order to find the total amount needed for any item, multiply the depth in feet by the figure found opposite the item desired and under the number representing the diameter of the silo. Suppose we wish to find the material needed for a pit silo 10 feet in diameter and 20 feet deep. The retaining wall is to extend 3 feet below the surface, leaving



Figure 9.—Wagon For Hauling Green Corn From Field.

17 feet of the wall to be plastered. In figuring the retaining wall and referring to Table II, Column 10, representing the diameter of the silo, we find that it takes 3.3 sacks of cement, 0.30 cubic yards of sand and 0.60 cubic yards of gravel for each foot in depth. Multiplying these numbers by the depth of the retaining wall, which is 3 feet, gives the total for each of the materials in the retaining wall.

Figuring the materials for plastering, we use the figures in Table II,

under the heading "Mortar for Wall," and under Column 10. According to this Table, it takes 1.2 sacks of cement and 0.094 cubic yard of sand for each foot in depth. Multiplying these numbers by the depth of the plastered wall, which is 17 feet, gives the total for each of the materials in the plastered wall. Completing the procedure as indicated above, gives:

Materials for Retaining Wall:

Cement 3′×3.3 sacks=9.9 sacks.
Sand 3′×0.3 cu. yds.=0.9 cu. yds.
Gravel 3′×0.6 cu. yds.=1.8 cu. yds.

Materials for Plastered Wall:

Cement 17′×1.2 sacks=20.4 sacks.
Sand 17′×0.094 cu. yds.=1.59 cu. yds.

TABLE II—Amount of Material Needed for Each Foot in Depth. Retaining Wall, 6″ in Thickness; Plastered Wall, 1″ in Thickness

DIAMETER OF SILO IN FEET ☞		8	10	12	14	16	18
Retaining Wall 1:2½:5	Cement, Sacks	2.6	3.3	3.9	4.5	5.2	5.8
	Sand, Yards	0.24	0.30	0.36	0.42	0.48	0.54
	Gravel, Yards	0.49	0.60	0.72	0.84	0.96	1.08
Mortar for Wall	Cement, Sacks	0.9	1.2	1.46	1.710	1.95	2.20
	Sand, Yards	0.075	0.094	0.11	0.132	0.150	0.169

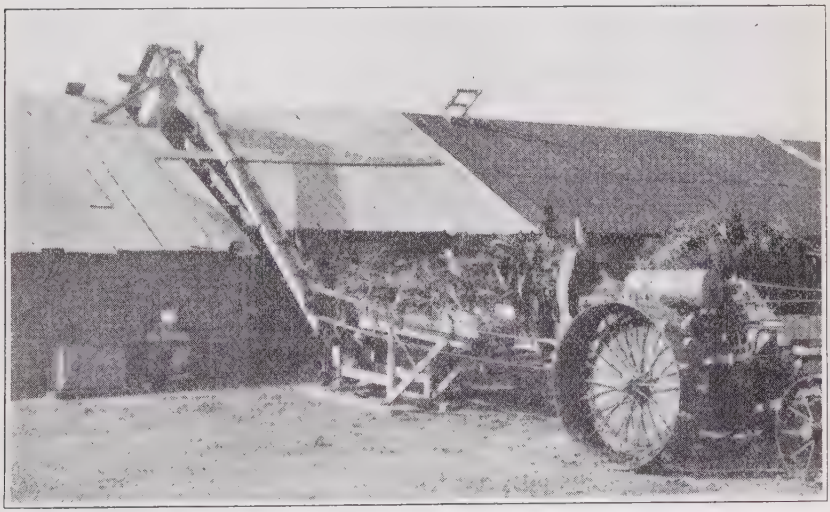


Figure 10.—Filling Pit Silos on Substation Farm, Cheyenne Wells.

Estimating Weights of Silage.—It is very difficult to estimate the capacity of a silo with any degree of accuracy, because there are so many factors involved. When filling is completed, the weight of silage per cubic foot will depend upon:

1.—Depth of silage.
2.—Moisture content.
3.—Proportion of grain to fodder.
4.—Thoroughness of packing.
5.—Rate of filling.
6.—Diameter of silo.

In 1917 the Nebraska Experiment Station published a circular which gives the average weight of a cubic foot of ensilage at different depths when filling is completed. Table No. III is taken from this circular and gives the capacity of different sized silos at different depths after filling is completed.

The Kansas Station published Bulletin No. 222 in 1919, which gives the weights of settled ensilage. The data were obtained jointly by the Missouri and the Kansas Agricultural Experiment Stations. Table No. IV is taken from this bulletin and gives the capacity of different sized silos at different depths after the ensilage had completely settled.

In either of these tables, the depth of ensilage rather than the height of the silo should be taken. If a portion of the ensilage has been removed, the best plan is to estimate the tonnage before any was removed and then the amount removed. The difference should be the amount on hand. For example, 28 feet of ensilage in a silo 14 feet in diameter is estimated by Table IV to weigh 83.4 tons. Suppose ten feet of ensilage is removed, and it is desired to know the tonnage remaining in the silo. According to Table No. IV, the ensilage in the first ten feet of a silo 14 feet in diameter weighs 26.9 tons. The tonnage remaining in the silo would be the difference between 83.4 and 26.9, or 56.5 tons.

When extreme conditions prevail, the Kansas bulletin 222 recommends that the following allowances be made.:

1.—When the corn is put into the silo in a less mature condition than usual, for example, in the milk stage, or at the beginning of the dough stage, add 10 to 15 percent to the weights given in the table.

2.—If the grain is unusually heavy in proportion to the stalk, add 5 to 10 percent to the figures as found by the table.

3.—If the corn is considerably past the usual stage of maturity and clearly contains less water than usual, deduct 10 to 15 percent.

4.—If very little or no grain is present, deduct 10 percent.

TABLE III—Estimated Tonnage of Silage at the Time Filling is Completed*

Depth of Silage	Average Weight Per Cu. Ft.	DIAMETER OF SILO IN FEET					
		10 Ft.	12 Ft.	14 Ft.	16 Ft.	18 Ft.	20 Ft.
Feet	Pounds	Tons	Tons	Tons	Tons	Tons	Tons
1	16.13	0.6	1.0	1.2	1.6	2.1	2.5
2	16.89	1.3	1.9	2.6	3.4	4.3	5.3
3	17.64	2.1	3.0	4.2	5.3	6.7	8.3
4	18.38	2.9	4.2	5.7	7.4	9.4	11.6
5	19.12	3.8	5.4	7.4	9.7	12.2	15.0
6	19.83	4.7	6.7	9.2	12.0	15.2	18.7
7	20.54	5.6	8.1	11.1	14.5	18.3	22.6
8	21.24	6.7	9.6	13.1	17.1	21.6	26.7
9	21.93	7.8	11.2	15.2	19.8	25.1	31.0
10	22.61	8.8	12.8	17.4	22.7	28.8	35.5
11	23.28	10.1	14.5	19.7	25.7	32.6	40.3
12	23.94	11.3	16.3	22.1	28.9	36.6	45.2
13	24.59	12.5	18.1	24.6	32.2	40.7	50.2
14	25.24	13.9	20.0	27.2	35.5	45.0	55.5
15	25.88	15.2	22.0	29.9	39.1	49.4	61.0
16	26.52	16.8	24.0	32.7	42.7	54.0	66.7
17	27.15	18.1	26.1	35.5	46.4	58.8	72.5
18	27.77	19.6	28.3	38.5	50.3	63.6	78.5
19	28.38	21.2	30.5	41.5	54.1	68.6	84.8
20	28.99	22.8	32.8	44.6	58.3	73.8	91.1
21	29.58	24.4	35.1	47.8	62.5	79.1	97.5
22	30.16	26.0	37.5	51.1	66.7	84.5	104.2
23	30.73	27.1	40.0	54.4	71.8	90.0	111.1
24	31.29	29.5	42.5	57.8	75.5	95.5	118.0
25	31.84	31.3	45.2	61.3	80.0	101.3	125.1
26	32.38	33.1	47.7	64.8	84.6	107.2	132.3
27	32.91	34.9	50.3	68.4	89.3	113.2	139.6
28	33.43	36.8	53.0	72.1	94.1	119.2	147.1
29	33.94	38.7	55.8	75.8	98.9	125.4	154.6
30	34.44	40.6	58.5	79.5	103.8	131.6	162.3
31	34.93		61.3	83.4	108.8	137.9	170.1
32	35.41		64.1	87.2	113.8	144.5	178.0
33	35.88		67.0	91.1	118.9	150.8	186.0
34	36.34		69.8	95.1	124.2	157.4	194.1
35	36.79			99.1	129.3	163.9	202.2
36	37.23			103.2	134.7	170.7	210.6
37	37.65			107.2	139.9	174.4	218.8
38	38.07			111.3	145.3	184.2	227.2
39	38.48			115.5	150.8	191.2	235.8
40	38.88			119.6	156.2	198.1	244.3

*Adapted from Nebraska Circular 1.

TABLE IV—Estimated Weights of Settled Silage*

Depth of Silage	Average Weight of Silage Per Cu. Ft. To This Depth	WEIGHT OF SETTLED SILAGE					
		10 Ft.	12 Ft.	14 Ft.	16 Ft.	18 Ft.	20 Ft.
Feet	Pounds	Tons	Tons	Tons	Tons	Tons	Tons
1	32.0	1.26	1.81	2.46	3.22	4.07	5.03
2	32.4	2.54	3.66	4.98	6.51	8.23	10.17
3	32.7	3.85	5.54	7.55	9.86	12.46	15.40
4	33.1	5.19	7.48	10.19	13.31	16.81	20.79
5	33.4	6.55	9.45	12.85	16.78	21.21	26.22
6	33.7	7.94	11.44	15.56	20.32	25.68	31.75
7	34.1	9.37	13.50	18.37	23.99	30.31	37.48
8	34.4	10.80	15.56	21.19	27.66	34.95	43.21
9	34.7	12.26	17.66	24.04	31.39	39.66	49.03
10	35.0	13.74	19.79	26.95	35.18	44.45	54.95
11	35.3	15.25	21.95	29.89	39.02	49.31	60.96
12	35.6	16.77	24.15	32.89	42.93	54.25	67.07
13	35.9	18.32	26.38	35.93	46.90	59.27	73.27
14	36.2	19.90	28.65	39.02	50.93	64.36	79.57
15	36.4	21.44	30.88	42.04	54.87	69.34	85.72
16	36.7	23.05	33.21	45.21	59.01	74.57	92.19
17	36.9	24.63	35.47	48.30	63.04	79.67	98.49
18	37.1	26.22	37.76	51.42	67.11	84.81	104.84
19	37.3	27.83	40.07	54.56	71.22	90.00	111.27
20	37.5	29.45	42.41	57.75	75.38	95.25	117.75
21	37.6	31.00	44.65	60.79	79.35	100.28	123.97
22	37.8	32.65	47.02	64.03	83.58	105.61	130.56
23	38.0	34.32	49.41	67.29	87.84	110.50	137.22
24	38.1	35.90	51.70	70.40	91.90	116.13	143.56
25	38.3	37.60	54.15	73.72	96.23	121.60	150.33
26	38.4	39.20	56.46	76.87	100.34	126.80	156.75
27	38.6	40.92	58.94	80.24	104.74	132.36	163.63
28	38.7	42.55	61.28	83.43	108.90	137.62	170.13
29	38.9	44.30	63.79	86.86	113.37	143.27	177.11
30	39.0	45.94	66.08	90.09	117.59	148.59	183.69
31	.....	47.63	68.51	93.40	121.90	154.06	189.94
32	.....	49.32	70.94	96.71	126.21	159.53	196.19
33	.....	51.01	73.37	100.02	130.52	165.00	202.44
34	.....	52.70	75.80	103.33	134.83	170.47	208.69
35	.....	54.39	78.23	106.64	139.14	175.94	214.94
36	.....	56.08	80.66	109.95	143.45	181.41	221.19
37	.....	57.77	83.09	113.26	147.76	186.88	227.44
38	.....	59.46	85.52	116.57	152.07	192.35	233.69
39	.....	61.15	87.95	119.88	156.38	197.82	239.94
40	.....	62.84	90.38	123.19	160.69	203.29	246.19

*Kansas Bulletin 222.

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The Colorado Experiment Station
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NECROBACILLOSIS

By GEO. H. GLOVER

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NECROBACILLOSIS

By George H. Glover

Few realize the rapid progress that is being made in reducing the loss of livestock from disease. The year-book of the Department of Agriculture for 1922 states that the annual loss of horses from disease has been reduced from 22.3 per thousand in 1895 to 16 in a thousand in 1922. This means that 150,000 fewer horses and mules die from disease in the United States in a year now than thirty years ago. The loss of hogs from disease and parasites makes even a better showing. In 1895 there was a loss of 92.3 hogs out of every thousand from disease, while in 1922 this loss was 54.4 a thousand. This means a saving of two and one-fourth million hogs a year and is attributed in a large measure to the use of anti-hog-cholera serum.

Not all of this saving is due directly to the ministrations of the veternarian for stockmen generally have acquired much knowledge of the proper care of animals in the prevention of disease. This knowledge has been disseminated in a large measure through the medium of the public press.

There is possibly no other disease about which there has been so much inquiry by farmers and stockmen of Colorado as *necrobacillosis*. The aggregate loss has possibly been greater than that from any other one disease, not excepting hog cholera.

In many sections of our State, no veterinarians upon whom stockmen can depend for advice are as yet available, and it is hoped that this bulletin may in a measure serve as an aid to those interested. The purpose of the bulletin is to give a practical summary of knowledge extant on the subject at this time, and to this end discussion of purely scientific phases of the subject will not be attempted.

DEFINITION AND HISTORY

Necrobacillosis is a generic term that applies to a group of diseased conditions caused by the specific germ, *Actinomyces necrophorus, (Bacillus necrophorus)*. It affects practically all species of domesticated animals, but is more common to hogs and sheep. When affecting the mouth it is called *necrotic stomatitis;* in the intestinal tract, *necrotic enteritis;* in the throats of calves, *calf diphtheria;* in the nasal chamber of hogs, *snuffles or bull-nose*. When affecting the feet it is known as *contagious foot-rot*, and in the skin, *necrotic dermatitis*. One

form common to sheep is *lip and leg ulceration.* It may affect any tissue of the body and is named according to the organ especially involved. The disease is well distributed over Colorado and has been known for many years. The heaviest loss seems to have occurred in the San Luis Valley. The aggregate losses are heavy because it affects so many species of animals and at all seasons of the year.

ETIOLOGY

The cause of the disease in all of its different manifestations is the specific germ, *Bacillus necrophorous,* of Bang. It is usually spoken of as the necrosis germ. To grow a crop of oats it is necessary to plant oat seed in a fertile soil; so here the one special germ must be implanted in the tissues under favorable conditions or there will be no disease. The micro-organism appears in different forms, (pleomorphic) under varied conditions, but it usually occurs in long threads both in laboratory cultures and in the invaded tissues. The threads contain granules particularly in old cultures. The bacillus is non-motile and does not form spores. When grown on laboratory media, air must be absolutely excluded. A pungent characteristic odor is emitted from the cultures and may be recognized in the lesions.

Unlike the specific germs of most diseases, the *B. necrophorus* is universally distributed and it appears that the intestinal tract of swine may be its natural habitat. In the intestinal tract it ordinarily causes no recognizable disturbance of health of the host, but thru either increased virulency of the organism or lowered resistance of the tissues it may become pathogenic. In such cases the pens, floors, yards, all surroundings, may become contaminated. In this way infection is usually indirect, but may be transmitted by contact as for example, a nursing pig infecting the udder of its mother. Indirectly infection may take place thru the medium of contaminated food or drink, thru inhaled particles of dust, thru abrasions of the skin, or even by copulation.

While the *B. necrophorus* causes disease in practically all animals, yet in most cases it is secondary, the resistance of the tissues having been lowered by previous disease such as an injury. The necrosis germ does not seem able to attack normal, healthy membranes. There is great weakness, followed by general emaciation, and this is noticeable even with primary mild infections. A few of the most common forms of *necrobacillosis* will be mentioned briefly, followed by a general outline of measures that might be adopted in the prevention and treatment in each instance.

NECROTIC STOMATITIS

The disease in this form is also mentioned as "canker", "sore mouth," and "ulceratice stomatitis." *Necrotic stomatitis* is the most serious form of inflammation of the mouth and is confined largely to pigs and calves. Pigs from a few days up to four months old are most affected. It occurs particularly in pigs that are farrowed in the fall, where the yards are muddy, and where they come in contact with harsh foods of any kind. The inflammation is most liable to start at the margin of the gums and may spread to the cheeks, tongue, and upper respiratory passages, or as a result of swallowing, the intestinal tract may become involved. Two or three days after the inflammation has started yellowish white or brown croupous-diphtheretic membranes form with deep seated ulcers beneath. It is attended by a general toxemia which causes extreme weakness from the beginning and leads to death within a few days. With calves, the first symptoms noticed are languor, disinclination to suck, drooling from the mouth and swelling of the cheeks. Little pigs show extreme emaciation and weakness and examination of the mouth will reveal the presence of one or more angry-looking deep-seated ulcers. Occasionally in a deseased herd a sick pig will be found without mouth lesions but on post mortem the characteristic ulcers will be found in the stomach, intestines, or elsewhere in the body. The disease frequently involves the nasal cavities and in the lungs may cause necrotic pneumonia.

Animals affected with *necrotic stomatitis*, unless treated early, will surely die. This disease must be treated on the same general principles as any other contageous or infectious disease. All of the calves or pigs should be examined and those that reveal no mouth lesions should be removed to clean quarters and kept under close observations thereafter. When ulcers or eroded areas are found they should be scraped with a dull instrument and treated with a one or two percent solution of silver nitrate, or a three to five percent solution of zinc chloride. The mouth should be irrigated frequently with a strong disinfectant solution. For this purpose probably nothing will be more satisfactory than a solution of potassium permanganate, one ounce to the gallon of water. A three or four percent boracic acid solution is an old, reliable remedy. In some cases caustics may be used to advantage. For this purpose lunar caustic is preferable. Hold the stick of caustic with pincers, or rolled in paper, dip the end of the stick in water and thoroughly rub over the surface of the ulcer.

Pigs that are badly diseased should be destroyed at oncee since there is no hope of recovery. After the sick pigs have been destroyed, and the mild cases treated, the others should be dipped and placed immediately in new, clean pens. For dipping, a half

barrel or tub will suffice. Potassium permanganate solution (.5 to 1 oz. to one gallon of water), or a four percent solution of one of the coal-tar disinfectants will be satisfactory and reasonably cheap. The pigs should be completely submerged with the head down.

CALF DIPHTHERIA

Calf diphtheria is differentiated from *necrotic stomatitis* on the grounds that is is essentially a calf disease and further that the lesions are confined more to the throat. It must not be confused with human diphtheria, between which there is no reciprocal relation and no similarity save in the formation of diphtheretic membranes. The symptoms, lesions, and treatment when possible, are practically the same as with *necrotic stomatitis.*

The importance of this disease should be stressed among farmers and stockmen. It attacks mostly young calves and very few survive. It commences on about the fifth day after infection, with marked weakness, diminished appetite, and a slight fever. A day or two later the calf refuses to eat, drools from the mouth, and the cheeks are swollen. An examination of the mouth and throat will reveal the presence of yellowish deposits and a ragged surface. Occasionally the lesions are confined largely to the larynx, and there will be difficult respiration, without mouth complications. Sometimes the nostrils are filled with a yellowish exudate and the respiration appears snuffling. It is a matter of common observation that where there is not a maximum of effort in curing the sick calves there is sure to be a minimum of effort in suppressing the infection. In other words, nothing is ordinarily done but treat the individual cases as fast as they appear. This is futile, for they nearly all die in from three to ten days, after showing the first symptoms.

The appearance of calf diphtheria must be managed on the same general principles as human diphtheria or any other highly contagious or infectious disease. Healthy calves should be immediately removed to clean quarters. Pregnant cows should be taken to clean quarters and kept there until their calves are at least three weeks old. The infected quarters should be thoroughly cleaned and disinfected.

From the standpoint of health a three-year rotation of animal quarters is of supreme importance. Where animals occupy the same quarters for a number of years they invariably become unhealthy. Unless the pens and yards are kept scrupulously clean they, after a time, become infested with parasites and germs of many diseases, making it practically impossible to keep them healthy.

LIP-AND-LEG ULCERATION OF SHEEP

Lip-and-leg ulceration of sheep is a form of *necrobacillosis* in which, as the name indicates, the lips and legs are most conspicuously involved.*

It has on occasion assumed a malignant form in Montana and Wyoming, causing considerable loss through deaths, abortion in ewes, and lost service of bucks. This disease is carried to Colorado with the importation of lambs every fall but fortunately under the conditions which exist the losses have never been very heavy. It is presumed that the specific germ, *B. necrophorus*, enters the skin lesions caused by cacti and other mechanically injurious plants.



Showing necrotic ulcers on the legs.

The first thing noticed in acute inflammation of the lips and quite commonly the skin on the legs about the coronet and fetlock joint. Pustules form, which soon erupt and, drying, form dark, gray-colored scabs. Ulcers form beneath the scabs that continually grow larger, manifesting little tendency to heal.

Each fall when lambs are shipped in for winter feeding a few flocks develop a scabby-lip condition soon after being placed in the feed lots. Most of these cases recover after a week or two but occasionally a few of them will develop deep-seated ulcers characteristic of the disease in question. The primary infection is no doubt induced by the change to harsh feed, and the scabby-lip condition which results is favorable to development of the secondary infection in a proportionate

*This should not be confused with Foot and Mouth Disease, which is foreign to the disease under consideration.

number of instances. Since the necrosis germ does not thrive in the presence of air it would seem best to soften and remove the scabs in so far as this can be accomplished without serious injury to the underlying tissue. The ulcers should then be cleaned with a dull instrument, being careful to remove all dead tissue. Next, lunar caustic should be used to disinfect the ulcer as outlined under the discussion of *Necrotic stomatitis*. The ulcers should be dressed daily thereafter. Healthy sheep should not be permitted to pasture on infected ranges for at least one year. Obviously under range conditions this precaution cannot always be observed, but when feasible it is a wise precaution against spread of the disease.



Showing Necrobacillosis of the Head

NECROTIC DERMATITIS

This is a form of *necrobacillosis* where the skin is essentially involved. It is more often seen in young pigs, the bacillus probably gaining entrance into the skin through abrasions caused by fighting. There are usually rather large necrotic areas, (see illustration herewith) which slough, causing irregular surfaces denuded of skin. Where the lesions become extensive there are grave systemic disturbances occasioned by absorption of poisonous products. These cases are hopeless, unless when the lesions are small the necrotic area can be entirely cut away, and appropriate treatment applied immediately and persistently. The treat-

ment as outlined above is appropriate in these cases. Pigs that are badly affected should be destroyed and the carcasses burned to insure safety against spreading the infection. The disease may appear in the form of large, hard tumors about the head, on the udder, or elsewhere on the body. These tumors develop very slowly, showing no tendancy to suppurate, but finally degenerate in the center, and if the pig survives long enough, will form into large, open, necrotic areas.

Necrobacillosis attacking the skin of horses and mules sometimes takes on an extremely malignant form that is hard to combat. During the war great losses occurred at the various army camps throughout the country. At one camp alone it is reported that 80 percent of deaths during the two months of July and August were due to *Bacillus necrophorus*. In horses and mules, more especially, the disease is sometimes spoken of as *gangrenous dermatitis*. It follows more often as a complication of "scratches," which is an eczematous inflammation in the region of the heel and fetlock. The exudate, combined, with dirt, dries into scabs which make the conditions ideal for the necrosis germ.

Nolecheck, of the U. S. Army, gives an outline of treatment for these cases which appears to have been highly satisfactory, and is as follows:

"*B. necrophorus*, being an anaerobe, each form must be treated with one object in view:—Expose the organism to the air. This is easily accomplished with the knife. In *gangrenous dermatitis* remove all nercrotic tissue and a part of the healthy structure, cutting away ragged edges of skin around the necrosed area. After the necrotic tissue is removed, apply bichloride pack, 1-500, leave pack 24 hours, remove and apply the following: Camphora pulv., liquor cresolis compositus, and phenol,—of each, 3 ounces; tincture of iodine, q. s., 1 quart. Apply with swab twice daily. If part becomes filthy, wash before applying. Bandaging at this time is contraindicated."**

NECROTIC ENTERITIS

It appears that inflammation of the intestinal tract attended with destruction of mucosa may be caused by a variety of microorganisms. Among these, in addition to the *B. necrophorus*, are various representatives of the para-typhoid group,—*B. suipestifer*, and the Gartner colon group.* *Necrotic enteritis* is of common occurrence, among pigs in Colorado. The indications are that there has been relatively a greater loss in Colorado from this disease than in any other state. It has existed in the San Luis Valley for many years and has constituted the most serious menace to the hog-raising industry.

**For open skin lesions powdered sodium perborate is highly recommended. The powder is applied in the form of a pack, being kept in place by means of a bandage.

Of course it is apparent that the services of a veterinarian are indispensable in treating these cases.

*The significance of certain animal parasites (protozoa) found with great frequency in the ulcers has yet to be determined. These organisms, namely,—"Trichomonas suis" and "Balantidium coli", appear with great constancy and the diarrhea is characteristic of an amebic infection.

There is a dearth of accurate data respecting the specific nature of *necrotic enteritis* in hogs. The fact that it is so frequently associated with *necrotic stomatitis*, "bull-nose," and necrosis of the skin makes it appear likely that it is in many instances at least, true *necrobacillosis*. However, the disease has a tendency to adhere strictly to the form in which it first made its appearance in the herd. If it starts in the form of contagious foot-rot in sheep it continues to appear in that form and there will be no cases of *necrotic stomatitis*, "bull-nose" or *enteritis*. The exception to this rule is the frequent occurence of *necrotic enteritis* and *necrotic gastritis* following infection in the mouth or throat.

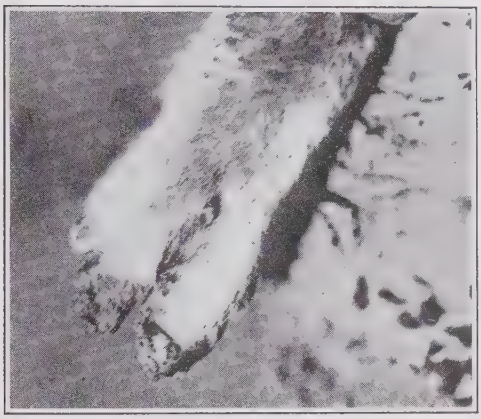
The first indications are diarrhea and unthriftiness. If the mouths are examined at this time there will frequently be found one or more ulcers, or by passing the hand downwards over the sheath with a firm pressure an exuade may be squeezed out of the preputial opening. The disease may assume a chronic form or complications may arise at any time, such as "thumps," or pneumonia, causing death. The infection usually spreads rather slowly, attacking first pigs from a few days old up to six weeks, until finally the whole herd appears unthrifty and many die.

Treatment would consist in separating the well animals from the sick ones. Badly diseased animals should be destroyed and their carcasses burned. Give strict attention to improving sanitary conditions. Unaffected pigs should be removed to clean pasture and the more range they have the better. Solid foods, such as corn, and other concentrates should be withheld for at least three weeks. Semi-solid buttermilk when available is considered the most appropriate food, since the lactic acid which it contains has an inhibiting effect upon the specific germs of infection. Among intestinal disinfectants copper sulphate has preference. Dissolve one pound of copper sulphate in a gallon of water and give this solution in the slop at the rate of one ounce to every 300 pounds live weight of animal, twice daily. Air-slacked lime has been recommended. To this end a bucket of quick lime may be dissolved in a tub of water and a quart of the solution mixed with the slop at each feeding. Fowler's solution of arsenic is to be considered because of its alterative, tonic, and antiseptic properties. A half teaspoonful for each little pig mixed with slop once a day will be appropriate. A veterinarian should be consulted respecting the use of bacterins.*

*Recent laboratory experiments seem to indicate that tincture of iodine as a disinfectant in drinking water ranks very high, and considering the fact that it is quite inexpensive, it might be considered in this connection. Fifteen drops to one quart of water will be strong enough.

CONTAGIOUS FOOT-ROT

All farm animals are subject to foot-rot, possibly sheep more than the others. It is usually associated with dirt and barn-yard filth. Mud sometimes dries between the claws to the consistency of a brick, which causes an abrasion, and this paves the way for necrophorus infection. Most outbreaks are infectious. After the lameness has become severe there is a slight discharge, with very offensive odor, and the hoof becomes rotten, usually in one spot which soon spreads to the deeper structures. After a fortnight the claws begin to separate, the animal is unthrifty and in great pain; the claws may slough, and the animal be unable to stand if more than one foot is affected. Cases of lameness in the feed-lots should not be neglected, —employ a veterinarian if possible. Clean the foot and pare away all dead tissue. Apply a two percent solution of silver nitrate or a five percent solution of zinc chlorid. Pine tar might then be applied, and bandages placed in such a way as to not only protect the foot from dirt but to keep the claws from spreading. Keep the animal on clean, dry ground.



Showing characteristics of foot-rot.

Sometimes it becomes necessary to treat a whole flock and special attention to individuals can not be accomplished. In such cases the sheep may be made to stand for five minutes in a pan containing an antiseptic solution. The solution should be deep enough to cover the feet. A solution made by dissolving one pound of copper sulphate in a gallon of water may be used, or dissolve one pound of fresh chlorid of lime in three gallons of water. This treatment should be repeated and continued as long as necessary. Separate the diseased animals from the herd and place them in a clean pasture.

An easier treatment, but probably not so effective, is to drive the flock over a large platform, (cleats may be placed around the edges) on which has been placed air-slacked lime several inches deep. Foot-rot in cattle and other farm animals should be treated on the same general principles, as outlined above for sheep.

NODULAR NECROSIS OF THE LIVER

Nodular necrosis is of common occurrence in cattle and is characterized by dry nodules in the liver substances which gradually undergoes a process of softening. Cases in sheep are rare and in other animals quite exceptional. It is presumed that in most cases the *bacillus necrophorus* reaches the liver through the portal blood stream from the intestine. Detection of the disease in life is practically impossible, and internal treatment is useless.

OTHER FORMS OF *NECROBACILLOSIS*

Ano-vulvitis is a form of the disease in question which affects the external genital organs of females. Starting, as it usually does, on the lips of the vulva, it may extend to the *anal mucosa* or the vagina. Several outbreaks of the disease in male animals have been reported where it assumed enzootic proportions. In one instance 125 steers in a feedlot were all affected. In male pigs it occurs as often in Colorado as in any other form of *necrobacillosis*. Both wethers and bucks are subject to it and usually with fatal termination. The first thing usually noticed is a scabby condition of the prepuce at the junction of the skin and mucous membrane. The infection may extend upward inside the sheath, in which case the penis is sure to become involved. Exudative material and urine may become imprisoned in the sheath because of the partial occlusion of the preputial opening. In an outbreak of the disease in cattle, in northwestern Missouri, Dr. A. T. Kinsley reported the use of the following treatment, which though simple was quite effective:—

"The lesions and surrounding structures were thoroughly cleansed with a three percent solution of liquor *cresolis compositus*, then the scab was detached and the necrotic tissue removed by means of a brush, curved scissors or curette. After the cleansing and the removal of the scab a small swab was used in cleansing the sheath of steers. The lesions on some of the animals were painted with an oleoginous mixture, composed of linseed oil three parts, turpentine one part, and on others, tincture of iodine was used. The treatment was repeated on the second day and again on the fifth day".

THE STATE AGRICULTURAL COLLEGE
OF COLORADO

The Thirty-Sixth Annual Report

OF

The Colorado Agricultural Experiment Station

FOR THE YEAR 1923

The Colorado Agricultural College

FORT COLLINS, COLORADO

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* On leave

LETTER OF TRANSMITTAL

To His Excellency, William E. Sweet, Governor of Colorado:

In accordance with the law of Congress establishing Agricultural Experiment Stations, I have the honor to transmit to you, herewith, the Thirty-sixth Annual Report of the Colorado Agricultural Experiment Station for the government fiscal year, July 1, 1922, to June 30, 1923.

The report covers a full financial statement of all receipts and disbursements, and brief summaries or outlines of the work done by those in charge of the different sections or departments of the Experiment Station.

C. P. GILLETTE,
Director

Agricultural Experiment Station
Fort Collins, Colorado.
December 1, 1923

FINANCIAL REPORT OF THE COLORADO AGRICULTURAL EXPERIMENT STATION FOR THE FISCAL YEAR ENDING JUNE 30, 1923

	Hatch Fund	Adams Fund	State Mill Levy Fund	Special Fund	Pure Seed Fund App'n.	Total Funds
DR.						
Balance July 1, 1922	.....	.....	$ 6,505.24	$ 6,373.56	$ 2,643.34	$ 15,222.14
From the Treasurer of the United States as per appropriation for the fiscal year ending June 30, 1923, under acts of Congress approved March 2, 1887 (Hatch Fund), and March 16, 1906, (Adams Fund)	$15,000.00	$15,000.00				30,000.00
Other sources than the United States			104,964.85	20,407.94	12,000.00	137,372.19
Total Receipts	$15,000.00	$15,000.00	$111,470.09	$26,781.50	$14,643.34	$182,894.93
CR.						
To salary	12,112.46	13,232.96	54,469.46	.....	3,896.54	83,711.42
Labor	401.28	62.35	9,193.93	693.50	626.83	10,977.89
Publications	190.75	.....	1,871.69	1.56	32.40	2,096.40
Postage and stationery	29.26	2.95	1,424.35	129.70	370.92	1,957.18
Freight and express	13.55	18.33	949.29	29.69	10.22	1,021.08
Heat, light, water and power	.....	.....	93.58	29.70	.....	123.28
Chemicals and laboratory supplies	87.81	703.18	882.05	7,767.49	2.60	9,443.13
Seeds, plants, and sundry supplies	275.25	53.28	1,406.42	783.18	142.11	2,660.24
Fertilizers	.....	.....	50.95	.....	.....	50.95
Feeding stuffs	254.93	83.27	6,487.41	1,620.56	.....	8,396.17
Library	71.35	8.00	517.22	13.50	6.00	616.07
Tools, machinery and appliances	.....	.....	1,597.77	.....	1.60	1,599.37
Furniture and fixtures	53.50	8.50	983.74	4,611.96	284.46	5,942.16
Scientific apparatus and specimens	825.82	631.38	3,879.32	1.50	28.00	4,916.02
Livestock	28.00	.....	7,210.69	.....	.....	7,238.69
Traveling expenses	451.33	195.80	4,400.29	649.89	757.88	6,455.19
Contingent expenses	.....	.....	977.00	194.75	.....	1,171.75
Buildings and lands	704.71	.....	4,386.78	461.13	13.60	5,566.22
Total expenditures	$15,000.00	$15,000.00	$100,781.94	$16,988.11	$ 6,173.16	$153,943.21
Balance on hand, June 30, 1923	.....	.....	10,688.15	9,793.39	8,470.18	28,951.72
Grand total	$15,000.00	$15,000.00	$111,470.09	$26,781.50	$14,643.34	$182,894.93

REPORT OF THE DIRECTOR

To the President:

Following is a brief report covering the work of the Colorado Agricultural Experiment Station during the Government fiscal year, July 1, 1922 to June 30, 1923:

The financial statement prepared by the College Accountant is confined strictly to the Government fiscal year, and gives a true record of balances and all money received and disbursed during the period covered. The reports from the various sections having been prepared for the most part during the month of November, include, in some instances, work done at a later date than June 30th.

Results of investigational work carried on in the field are often affected by weather conditions. In some instances, unfavorable weather has interfered with Station work the past year, but, on the whole, the investigational work has seemed to the writer to progress as well as in average years. There are phases of the work deserving special attention, but rather than give what might seem to be undue prominence to any of these, I will allow each report to speak for the work of its respective department.

There are frequent calls on the part of the workers for additional funds to permit them to put on new investigations or enlarge the scope of those already being pursued. While in nearly all cases these requests are reasonable and should be granted if possible, the funds of the Station are definitely limited and it has been our policy to urge the completion of work on present projects before taking up new ones, and to intensify the work on a few of Colorado's most important problems rather than try to cover a larger number of problems and be compelled to touch them too lightly to reach dependable results.

A few additional projects have been approved during the past year in excess of the number that have been completed or put in abeyance. These occur almost exclusively in the new section of Agricultural Economics and in Animal Husbandry. In the former section, the added work and expense was made possible because of the provision made by the 24th General Assembly for the support of a department of Agricultural Economics in the College, because we were able to co-operate with the U. S. Department of Agriculture in carrying on our investigations, and because the Station funds were somewhat relieved by not having to pay heavy fire losses the past year. The investigations were made necessary by the strong demands of the farmers for help in this line and the evident great necessity for it.

The additional problems in the Animal Husbandry section were put on without additional expense except that incurred in taking over the project on Lamb Losses in Feedlots formerly carried by the Pathology Section. This was done because Dr. Newsom, of the Pathology Section, had come quite definitely to the conclusion that the particular

lamb losses that were being investigated were due to feeding problems and not to specific diseases.

The number employed in investigational work remains practically the same as last year, there being 16 regular employees devoting their time exclusively to Station work and 28 dividing their time between Station and College duties.

It is a pleasure to report that there have been but three resignations from the Station staff during the year, none of them heads of sections, and three new employees have taken their places.

The total Station budget approved for the fiscal year 1921-22 was $137,075. of which $5,000 was to cover fire losses $3,630 for the purchase of water rights, $3,035 for publications, leaving $125,410 for the actual investigational work.

The 24th General Assembly made a special appropriation of four thousand dollars ($4,000) for the better equipment of the Cheyenne Wells branch station. and a special appropriation of ten thousand dollars ($10,000) to be met by a like appropriation by the Commissioners of Weld County, for the purchase of land and equipment for the Greeley Potato Station which is conducted by the Bureau of Plant Industry of the U. S. Department of Agriculture in co-operation with the Colorado Experiment Station. These funds, however, will not be spent until the coming fiscal year.

The loss of the old chemistry building and contents by fire on the night of December 22, 1921, was a serious setback to the investigation of that section, as it was not until February, 1923, when the new quarters were fully equipped for the resumption of the work. However, in the reconstructed building the space and facilities for chemical investigations have been greatly improved so that the section is now much better equipped than ever before for its work.

The investigations of the Chemistry Section are still confined chiefly to soil problems of the State as related to the formation and accumulation of harmful quantities of nitrates due to the action of soil bacteria (*Azotobacter sp.*). The extreme importance of the nitre problem to Colorado and other portions of the arid West was first discovered and made known by Dr. Wm. P. Headden, and later studied by the Chemistry Section in co-operation with Dr. Sackett of the Bacteriology Section. During the past two years the sections of Agronomy and Irrigation Investigations have been included in the co-operative work of investigating soil trouble in the Arkansas Valley, where we have also had the splendid co-operation of the American Beet Sugar Company, in an attempt to determine what can be done to correct the evil. I am glad to report that very encouraging results have been secured, the work will be continued, and all data secured to date are in harmony with the early conclusions of Dr. Headden, supported by Dr. Sackett, that the source of the excessive nitrates is in the action of *Azotobacter sp.* in the soil, and that, in all probability, it can only be

corrected economically by such agricultural practice as will make conditions unfavorable for the development of these organisms.

Following is a list of the sections, along with the projects carried by each during the past year:

AGRICULTURAL DIVISION

Agronomy Section

Relation of Soil Moisture, Structural Development and Acre Yields in Small Grains. Adams and State Funds.

Correlation of Characters in Grain. Hatch and State Funds.

Methods of Selection Breeding. State Funds.

High-Altitude Crops. State Funds.

Plains Crops and Management. State funds and special appropriations.

Arkansas Valley Nitrate Control. (In co-operation with Bacteriology and Irrigation Investigations).

Animal Investigations Section

Acre Value of Pasture for Dairy Cows. State Mill Levy.

Ration Experiments with Steers. State Mill Levy.

Rations for Fattening Lambs. State Mill Levy.

Range Improvement. State Mill Levy.

Winter Maintenance of Breeding Ewes. State Mill Levy.

Summer-Fallow Experiment at Akron, Colorado. State Mill Levy.

Supervision in Dairy-Cow Records. State Mill Levy.

Bacteriology Section

Heat-Resisting Bacteria in Fresh and Canned Vegetables. Adams Fund.

Value of Certain Carbon Compounds as a Source of Energy for Azotobacter. Adams Fund.

Active Principle of Whorled Milkweed. Adams Fund.

Arkansas Valley Nitre Investigation. State Mill Levy.

A Bacterial Disease of the Wragg Cherry. Hatch Fund.

Botany Section

Hard Seed of Alfalfa. State Mill Levy.

Range Improvement. (Co-operation with Animal Investigations). State Mill Levy.

Plant-Disease Survey. State Mill Levy.

Biologic Specialization of Parasitic Fungi in Relation to Disease Resistance. Adams Fund.

Chemistry Section

Nitre in Colorado Soils, its Occurrence, Formation and Effects upon Vegetation. Adams Fund.

(a) Relation of Nitrates to Potato Diseases in the Greeley District, Colorado.

Entomology Section

Plant-Louse Investigations. Adams Fund.

Ants of Colorado in their Relation to Plant Lice. Hatch and State Mill Levy.

Codling-Moth Control. Hatch and State Mill Levy.

Grasshopper Control. State Mill Levy.

General Insect Investigations. State Mill Levy.

Economics and Sociology

Marketing Investigations, in co-operation with the Colorado division of Markets, State House, Denver, Colo. State Mill Levy.

Settlers' Progress Study, in co-operation with the Division of Land Economics and the Office of Farm Management and Farm Economics, U. S. Dept. of Agriculture. State Mill Levy.

Cost of producing Beef Cattle on the Range, in co-operation with Cost of Production and Farm Management Division, U. S. Dept. of Agriculture. State Mill Levy.

Farm Organization and Costs on Farms in the Greeley Area, in co-operation with Division of Farm Management and Farm Economics, U. S. Dept. of Agriculture. State Mill Levy.

Rural Life Studies. Three sub-projects have been taken up under this general heading. One was carried in co-operation with the Rural Life Section of the Bureau of Agr. Economics, U. S. Dept. of Agriculture. State Mill Levy.

Forestry Section

Studies in the Decay of Wood. Hatch Fund.

Home Economics Section

Cooking Quality of Colorado Potatoes. State Mill Levy.

A Study of the Bread-Making Qualities of Colorado Flours. State Mill Levy.

Horticulture Section

Potato Investigations. Hatch and State Mill Levy.

Seed-Potato Growing in High Altitudes. State Mill Levy.

Hardy Tree-Fruits for High Altitudes. State Mill Levy.

Tomato Variety Tests. State Mill Levy.

Head Lettuce in High Altitudes. State Mill Levy.

Irrigation Investigations Section

Evaporation Experiment. Hatch Fund.
Meteorology. State Mill Levy.
Measurement of Water as Applied to Irrigation. Hatch Fund.
Arkansas Valley Nitre Investigations. State Mill Levy.

Pathology Section

Contagious Abortion. State Mill Levy and Hatch Funds.
Sheep Losses in Feedlots. Hatch Fund.

Veterinary Section

Animal Diseases. State Mill levy.

ENGINEERING DIVISION

Civil Engineering Section

Road Materials of Colorado. State Mill Levy.

Mechanical Engineering Section

Methods of Handling Hay in Colorado. State Mill Levy.
Heat Transmission of Commercial Wall Board. State Mill Levy.
Treatment of Alkali and other Waters for Domestic Use. State Mill Levy.
Testing of Lubricating Oils. State Mill Levy.

Following are brief reports upon the work of the year from the heads of sections.

Respectfully submitted,
C. P. GILLETTE, Director

REPORT OF THE AGRONOMY SECTION

To the Director:

The work of the Agronomy Section for the fiscal year ending June 30, 1923 is appended below. The following projects have been active:
Relation of Soil Moisture. Structural Development and Acre Yields in Small Grains. Adams Fund and State Funds.
Correlation of Characters in Grain. Hatch Fund and State Funds.
Method of Selection Breeding. State Funds.
High-Altitude Crops. State Funds.

Plains Crops and Management. State Funds and Special Appropriations.

Arkansas Valley Nitrate Control. State Funds.. (In co-operation with Bacteriology and Irrigation Investigations.)

The above projects have been approved for work during the fiscal year. July 1, 1923 to June 30, 1924.

Relation of Soil Moisture, Structural Development and Acre Yields in Small Grains:

The use of Marquis spring wheat was continued under this project, which for shortness we have called "Critical Periods" in our work. Specific and annual results have been reported to you from time to time. This work has now gone far enough so that we feel that a preliminary report can be worked out for publication. We would recommend the publication of a progress bulletin and perhaps also of the submission of a manuscript to the Research Journal for publication.

This year we had an unusual opportunity for testing the effectiveness of our methods of protection against undesired water. As you know the plats are covered in times of threatening rain with canvas covers with drains at the side to remove any precipitation. On Thursday, July 26, we had a rainfall of 2.13 inches, according to the rain guage located within a few feet of the plats. This rainfall came within twenty minutes. Our system of covering and water removal was sufficient to absolutely protect the plats even with this unprecedented precipitation. We can, therefore, say with assurance that our plans for protection against undesired or accidental moisture are quite successful. We continued the trial of potometers to check against field plats. So far the field plats have been very much more successful.

Correlation of Characters in Grain:

No new plantings were made for the study of correlation of characters in 1923, but we had on hand in our field laboratory several thousand plants grown in previous years for study. We hope to gather material enough to close this project either this year or in 1924, at least in its present form. There are features of the work which have arisen because of the project that are worth further investigation. For that reason it may be desired to continue the project for sometime after the main line of work has been written up and filed.

Alfalfa Breeding:

We are doing very little work in alfalfa breeding at the present time, only enough to hold a few of the seed stocks with which we have sometimes worked in the past. The larger attention which we have been obliged to give to the Arkansas Valley nitre problem has necessitated a reduction of our alfalfa-breeding work to the minimum. We are

more or less convinced that the nitrate problem is associated with the problem of low seed production, which we have faced in our alfalfa-breeding work in the past. We can breed new and desirable varieties of alfalfa. Formerly we could produce seed in abundance but in many of the old seed-producing regions it is now so extremely uncertain whether or not seed will be produced, that we are obliged before proceeding vigorously with this project to find reasons for low seed production where seed production was formerly good.

High-Altitude Crops:

Work on the high-altitude-crop project has been largely confined to Fort Lewis. We have had some work going in other sections of the State. The main body of our work, however, has been at Fort Lewis. During the past year our Fort Lewis high-altitude work has been in direct charge of Mr. Harrison D. Horton. Mr. Horton has given very satisfactory attention to the work. At present our high-altitude work is limited to a study of adapted types of crops. We feel that this preliminary work must be done first. It is of very great importance to settlers in high-altitude regions. Besides this immediate use, the determination of adapted types is extremely useful for crop-improvement work to be taken more seriously later on.

Mr. Horton is now at work on his annual report for the 1923 summer season, which will be filed with you when completed. We enlarged the work somewhat this year by adding forage and pasture crops to the investigation.

Seed-Crop Improvement Work:

1. We are doing pure line breeding in the attempt to isolate valuable pure line strains from our best adapted standard sorts.

2. We are importing and testing varieties of grain and forage crops with the view to determining the best of these in their adaptability to our conditions.

3. We are purifying existing good varieties or strains which have become mixed thru some accident or otherwise in order that the pure strains may be again put into production without mixtures.

4. We are attempting to produce absolutely new things by making cross fertilizations between existing types. The parents in each case are chosen because of some desirable quality contained in each of two different parents but not in any one strain. We believe that we can be of best service in producing new strains, in determining the valuable sorts and then as quickly as possible getting those strains to the hands of growers. We consider it a duty, however, to first determine the value of those strains before we put them out.

In order to get a new variety or a new strain generally adopted it is necessary to produce large quantities of seed. This can best be done by getting the new strain into the hands of farmers, who have

capabilities as seed growers. If we put all of our available land into a strain to increase it, it would only supply a relatively small number. By getting good things into the hands of farmer growers, good things can be spread with great rapidity because the acreage devoted to such good strains can be increased far beyond the capacities of our plant.

We are now putting on the market Colsess, a very promising new barley of hybrid origin. Colsess is the result of the development of one strain from a cross between Coast, commonly called California Feed, and a strain of Success locally known as Beardless. We have six year's tests of this variety at Fort Collins and four year's test at Fort Lewis. At Fort Lewis as the average of the four year's test, Colsess stands first from point of yield. At Fort Collins it stands second in yield among all barleys. We have sent samples to adjoining states for test at their Experiment Stations with good reports in every instance. The report we get everywhere is that Colsess is the highest yielding beardless or hooded-type barley tested. We expect to use extra effort to get this barley propagated and grown in the higher altitudes. Its beardless character together with high yield makes it especially desirable for high-altitude barley production. It can be grown for thrashed grain. It can be used in pea-barley mixtures. It may be pastured with perfect safety as there are no beards. It may be cut for barley hay. It may be pastured off with livestock without danger of sore mouth. which is one of the troubles quite prevalent with such varieties of bearded barley as Coast, which has a very heavily barbed beard.

Plains Crops and Management:

The legislature of 1923 appropriated a small sum for use in our experimental work at Cheyenne Wells. This appropriation fund augmented by our regular Cheyenne Wells support for investigation of crops adapted to our plains, is being utilized at Cheyenne Wells. We are increasing our building plant somewhat at the Cheyenne Wells farm.

Crop production on the plains is an up-and-down affair, good one year and poor the next. For some years we have been working on the idea of producing and storing a reserve feed supply. This program we are helping forward by putting down four additional silos, by increasing shed storage room to take care of some other feeds. A successful and permanent agriculture on the plains must be a mixed type of farming; first, because the surest crops are feed crops, which must be utilized by livestock; second, because a variety of crops must be grown so that if one fails something may be obtained from the others. We have been working steadfastly on this fundamental idea for a number of years and have made considerable progress. We enlarged the work at Cheyenne Wells this year by a comprehensive set of small forage plats. We will continue these forage plats in pasture mixtures as a part of the future program.

I may say that our plains soy-bean tests conducted at Cheyenne Wells and at Akron are giving promise of an additional leguminous

crop to help out the feed situation. It looks as if we could produce yields as high as is possible with pinto beans. The soy bean, owing to its high oil content as well as its high protein content, is valuable for feed and if it can be produced in quantity will have a definite market as a cash crop.

We are continuing the studies of pasture-cropping legumes and their management.

We are not able to take up all of the problems that should be investigated. During the year we have made partial arrangements with the Office of Dry Land Agriculture and the Cereal Office of the Bureau of Plant Industry, looking forward to co-operation at Akron with those offices in the future. Co-operative arrangements have not been completed but preliminary negotiations have been carried out. We have a quarter section of land at Akron adjoining the Government 60 acres. Furnishing this land for the use of the Government and conferring frequently with the Government workers enables us to obtain a large amount of information on methods of dryland agriculture for northeastern Colorado.

Our Cheyenne Wells plant needs further enlargement and support to settle the dryland problems for central eastern Colorado. Sometime it will be necessary to do more experimental work in the extreme southeastern portion of our plains. Just what the farm unit should be for the average plains farmstead is not yet determined. We should have a larger body of land upon which this might be worked out as a practical problem. Preferably this should be done at Cheyenne Wells.

Arkansas Valley Nitrate Control:

Since making the last report definite arrangements for continuous chemical checks have been made. Mr. Justus C. Ward was placed upon an annual salary basis to give a continuous picture of the chemical changes in the soil. In 1922 samplings were taken to a depth of 4 inches only. The samplings were made every two weeks, beginning in the fall of 1922 and continued in our 1923 and 1924 plans. Once every month samplings are taken by four-inch cores to a depth of 6 feet, in order to get a picture of nitrate changes and movement in the soil itself.

In last year's annual report, mention was made of the fact that it would be desirable to follow the percentages of some other constituents than nitrates. Beginning with the fall of 1922 studies were made on the chlorine or chloride contents of every sample analyzed for nitrates. Mr. Ward made a study of the agreement or disagreement of chlorine and nitrate contents in 1,982 samples studied. If in a specific sample of soil the chlorine content rose with the nitrate content or fell with the nitrate content, that is if it changed up or down in the same direction with the nitrates it was placed in the class as agreeing in fluctuation with the nitrates. If on the other hand the chlorine content varied in a different direction than the nitrate it was placed in a class as dis-

agreeing. It made no difference what the order of agreement or disagreement was if the variation was with the nitrate it was marked as agreeing and if it was contrary it was marked as disagreeing. Arranged in this way a thousasd samples showed an agreement in the rise or fall of chlorine and the nitrate content and a disagreement in 982 cases. In other words there was no relation between nitrate and chlorine concentrations. One thousand to 982 is about as near a 50-50 arrangement as could be made with that number of variants. Such a distribution indicates that there is no relationship between the movement of the two.

In attacking our problem the three co-operating sections—Agronomy, Bacteriology and Irrigation Investigations—have had the use of 40 acres of the Station farm and have actually used about 50 acres of one of the sugar company farms at Rocky Ford. The plans on the sugar company farm are primarily to show the possibilities of control and what controls are possible with nitrates with special reference to the sugar-beet crop.

On the Experiment Station farm we have attempted more to get at fundamental plans of control with the expectation that we would work out a definite system of relationship later. This plan is being adhered to. Arrangements have already been made for the continuance of the Sugar Company's co-operation, because it furnishes a valuable additional set of data in the attempt to solve the problem. In addition to agricultural methods which we are stressing most strongly thru green manures, rotations and crop and soil management, we are also trying the effect of certain chemical corrective measures. Some of these chemical measures have given considerable flattering promise.

General Comment:

The Agronomy staff for the year has consisted of Alvin Kezer, Agronomist; D. W. Robertson, Associate; G. Warren Deming, Assistant at the Fort Collins plant; P. K. Blinn and Justus C. Ward at the Arkansas Valley plant; Harrison D. Horton at the Fort Lewis plant and J. W. Adams at the Cheyenne Wells plant. Mr. Joseph F. Brandon and F. A. Coffman of the U. S. Department of Agriculture have rendered very valuable assistance thru the turning over of results that they have obtained at the Akron plant. We can strongly recommend the consummation of definite co-operation.

It seems advisable for the coming fiscal year to enlarge the plans in the Arkansas Valley to include jointly with the Bacteriology Section a spray program as a part of the protection of crops against virulent plant-disease infections.

Respectfully submitted,

ALVIN KEZER,
Agronomist

REPORT OF THE ANIMAL HUSBANDMAN

To the Director:

Following is a list of projects that have been carried on in our section during the present fiscal year:

Acre Value of Pasture for Dairy Cows—E. J. Maynard in Charge
Ration Experiments with Steers—E. J. Maynard and G. E. Morton
Rations for Fattening Lambs—E. J. Maynard in Charge
Range Improvement—E. J. Maynard in Charge
Winter Maintenance of Breeding Ewes—Chas. I. Bray in Charge; L. K. Crowe for current year.
Summer-Fallow Experiment at Akron, Colorado—E. J. Maynard in charge
Supervision in Dairy-Cow Records—Chas. N. Shepardson in Charge.

Following is a list of projects planned for the coming fiscal year, all of which are on the State Mill Levy Fund:

Acre Value of Pasture for Dairy Cows—G. E. Morton and B. W. Fairbanks
Ration Experiment with Steers—E. J. Maynard and G. E. Morton
Rations for Fattening Lambs—E. J. Maynard in Charge
Range Management—E. J. Maynard and G. E. Morton
Winter Maintenance of Breeding Ewes—Chas. I. Bray in Charge
Summer-Fallow Experiment at Akron, Colorado—E. J. Maynard in Charge
Supervision of Dairy-Cow Records—Chas. N. Shepardson in charge; L. K. Crowe for current year
Sunflower Silage for Dairy Cows—B. W. Fairbanks in Charge
Death Losses Among Lambs in Feedlots in the San Luis Valley—E. J. Maynard in Charge
Investigations into Methods of Financing the Cattle Industry—Chas. I. Bray in Charge
Incubation Experiments with Poultry—O. C. Ufford in Charge
Value of Mineral in Mixed Rations for Swine and Cattle—Chas. I. Bray in Charge

The ration experiments with steers were run in series of three years, and we are getting useful results with regard to Sugar Beet Tops, Corn Silage and Sunflower Silage in fattening rations.

The most important result with sheep has been in finding the feeding value, in rations, of beet molasses. We are now investigating the value of the method of feeding called "lambing off" corn.

We are now holding Cattle Feeders' and Lamb Feeders' Days just before the stock is sent to market, and this is causing a rapid spread of knowledge of the results secured.

I believe the chief problem this section has to face is that of providing for the future of the poultry experimental work. The prob-

lems are great enough and the industry sufficiently important to demand attention at our hands.

Respectfully submitted,
GEORGE E. MORTON.

REPORT OF BACTERIOLOGIST

To the Director:

I have the honor to submit herewith the annual report of the Bacteriology Section of the Experiment Station for the fiscal year ending June 30, 1923.

Our studies covering this period have been, for the most part, continuations of the projects of the previous year; however as our work has progressed it has been found necessary to modify the line of procedure as originally planned in two instances. Three of the projects have been supprted by the Adams fund, one by the Hatch, and one by the State funds..

We have continued to furnish vinegar cultures to the farmers and commercial vinegar plants all over the United States, and judging from the reports and orders received from former customers, they are giving excellent results.

In addition to our research work, an appreciable amount of time has been consumed in the examination of the numerous samples of water, soils and diseased plants, which are referred to this laboratory by correspondents.

Adams Fund Projects

1. *Azotobacter*

Energy Studies:

Further studies have been conducted upon the part which green manures may play in retarding or stimulating the fixation of atmospheric nitrogen in soil by *Azotobacter*. We have endeavored to find out whether the decay of the green crops would produce sufficient acid to exercise any injurious action upon the nitrogen-fixing bacteria as measured by a lag in the normal increase of total nitrogen; second, whether the crop residues would ultimately act as an additional source of energy for the *Azotobacter* and stimulate their growth to a point where there would be a measureable increase in total nitrogen. Corn, barley, oats, millet, Sudan grass, and rye served as green crops, and in addition to these sulfur was employed as a possible source of acid. Soil from both the Crowley and Rocky Ford districts was used in the experiment.

2. Spoilage in Canned Vegetables:

Because of the difficulty we have experienced in securing home-packed vegetables for our investigation, we have had to confine our work mostly to commercially canned products. The list includes beans, peas, corn, mixed pickles, pears, raspberries, logan berries, minced meat, salmon and corned beef. From the commercially canned goods we have been unable to find any micro-organisms whatever, which led us to believe that either the micro-organisms had died out or there was no spoilage. As a matter of fact, none of the commercial pack exhibited either abnormal appearance or odor, and it is altogether possible that the store keeper's judgment on the "spoiled" goods was based upon insufficient evidence.

Because of the increasing number of cases of botulism poisoning traceable to home-canned vegetables, we have given some attention to the occurrence of *B. botulinus* in soil as a possible source of the contamination.

3. Milkweed Poisoning:

The material which was collected for our work on the active principle of *Asclepias galioides* during the summer of 1922 was so low in potency that no satisfactory extract could be prepared unless very large quantities of the weed were used, and this was found to be impracticable. As had been noted before, the potency of the plant appears to diminish as the blossoming time approaches, and the season of 1922 being unusually dry, the plants came into flower nearly a month earlier than normal. Inasmuch as we had not anticipated this early maturity of the crop until it was too late to obtain other material, we found ourselves without a suitable supply for further investigations.

HATCH FUND PROJECT

1. Bacterial Disease of the Wragg Cherry:

The disease was present in the Crowley district to a somewhat greater degree than in 1922. It was also observed at Rocky Ford, but the damage to the crop was practically negligible.

We have again isolated the same bacillus from diseased cherries as in former years, and have made inoculation on both leaves and fruit. Negative results were secured on the leaves with nine different cultures, but spots suggestive of the disease were produced on the cherries themselves with several of the cultures.

STATE FUNDS

1. Arkansas Valley Niter Investigation:

The Rocky Ford laboratory, which was opened in the spring of 1922 for the purpose of following systematically the development of

soil nitrates in that section of the State, has yielded results far beyond our expectations.

The weather conditions in 1922 and 1923 were so different from the standpoint of precipitation that comparisons of the analytical results of our soil analyses for the two years is futile; however, we have had a most excellent opportunity of observing the relation of extreme moisture conditions to nitrate development and accumulation.

The necessity for continuing the sampling thruout the year became apparent early last fall after harvest, and accordingly arrangements were made to retain Mr. Ward as chemist on a twelve months basis. Subsequent work has demonstrated the wisdom of this change in our original plan, which contemplated operating the laboratory only until late fall.

The need for analysing a larger number of surface samples, as well as samples taken to a depth of six feet, was felt last year and this spring we added the necessary equipment to the laboratory to handle the extra work. In consideration of the soil analyses which we are making for the American Beet Sugar Company in connection with our co-operative plots on the Company farm, the Company has given us part time of one assistant to help Mr. Ward with routine operations in the laboratory.

The results of our first year's work upon the project have indicated rather clearly which crops can be grown to advantage upon high niter soils, both for the good of the soil and the crop; they have suggested a feasible rotation for the utilization of the nitrates and the control of their formation; they have shown certain crops, previously considered desirable for the control of nitrate accumulation, to be unsuitable for this purpose; finally, they have given additional support to the biological explanation of nitrate accumulation by showing the absence of any relation between soil nitrates and chlorides.

A brief report by Mr. Ward follows:

To the Director:

The work of the Colorado Experiment Station Laboratory at Rocky Ford during the fiscal year has been continued under the joint supervision of the Agronomy and Bacteriological Sections of the Experiment Station, and has been confined to the problems related to Arkansas Valley Nitre Control.

Investigations have been conducted on the Station Farm at Rocky Ford, and on fifty acres belonging to the American Beet Sugar Company at that place. Nitric nitrogen variations in the surface four inches of the soil on all the plots of both farms were noted at two-week intervals thruout the year. Sub-soil nitrates were examined to a depth of six feet on selected plots of each farm each month.

Results of the study this year have corroborated previous findings, in that seasonal averages show similar tendencies; namely, the nitro-nitrogen values of those plots planted to cultivated crops are again consistently higher than those of fields growing small grains, clover, or alfalfa. This correlation is the more valuable because of the strikingly different moisture conditions of the two seasons.

Plans for the coming season contemplate an extension of the investigations to again include privately owned farms in the vicinity of Rocky Ford.

where lack of time this year made it necessary to discontinue work started in 1922.

In addition to the nitric-nitrogen determinations made during the past year, the amount of chlorine present in each soil was found also. This work is to be continued and extended as time permits.

Respectfully submitted,

JUSTUS C. WARD,
Chemist, Rocky Ford Sub-Station.

This report would be incomplete without a word of appreciation for the additional laboratory space on the third floor of our building. These two rooms will be used for our soil and hydrogen-ion determination investigations. Eventually I hope to fit up one of these for a biochemical laboratory.

To the director I wish to express my appreciation for the generous and sympathetic support he has given our work, and to Miss Brown and Mr. Ward like appreciation for their faithful and efficient service.

Respectfully submitted,
WALTER G. SACKETT,
Bacteriologist

List of Projects for Fiscal Year 1922-1923.

1. The value of certain carbon compounds as a source of energy for *Azotobacter*. Adams Fund.
2. Heat resisting bacteria of fresh and canned vegetables, and their relation to spoilage. Adams fund.
3. Food poisoning in sheep and cattle. A study of the active principle of whorled milkweed *(Asclepias galioides)*. Adams fund.
4. A bacterial disease of the Wragg cherry. Hatch Fund.
5. Soil nitrates in the Arkansas Valley. State Fund.

List of Projects for Fiscal Year 1923-1924.

1. The value of certain carbon compounds as a source of energy for *Azotobacter*. Hydrogen-ion concentration studies. Adams fund.
2. Heat-resisting bacteria of fresh and canned vegetables, and their relation to spoilage. Occurrence of *B. Botulinus* in soil. Adams fund.
3. Food poisoning in sheep and cattle. A study of the active principle of whorled milkweed *(Asclepias galioides)*. Adams
4. The natural inoculation of Colorado soils with legume bacteria. Hatch fund.
5. A bacterial disease of the Wragg cherry. Hatch fund.
6. Soil nitrates in the Arkansas Valley. State Fund.

REPORT OF THE BOTANY SECTION

To the Director:

I beg to submit the following brief report of the work of the Botany Section for the past fiscal year:

The Range-Improvement work has been carried along the lines previously outlined. Emphasis has been placed on the study of clipped quadrats this year. Two new series of quadrats have been added with the view of a more intensive study of yield factors. While these series are expected to yield data especially applicable to Wheat grass and Buffalo grass, the general results will be applicable to the other species occurring on the range.

In the investigation of the native rubber-producing plants in Colorado, special attention has been given to *Hymenoxys floribunda* which is very abundant on the Western Slope and which is considered by some as being of some commercial value. Histological analyses have been made to determine the distribution of rubber within the plant. Chemical analyses of the primary and multicipital roots have also been made.

A preliminary report of the work done on the project of Hard Seed in Alfalfa is being prepared for publication.

The work carried on with the different varieties of beans both here and at Rocky Ford for the past three years under the project Biologic Specialization of Parasitic Fungi has been discontinued and the data is being prepared for publication.

The Plant-Disease-Survey work shows a very great prevalence of cereal diseases in the State this year. The rusts, smuts and *Helminthosporium* diseases caused considerable loss to the grain growers of the State. Epidemology studies of the black stem-rust and investigational work on the wintering over of the red-rust spore of this fungus has been carried on during the past season.

Some preliminary work has been started on the *Coryneum* Blight of the peach and apricot. Celery Yellows and the Powdery Mildew of the apple are becoming more and more prevalent and some investigational work ought to be done on these diseases. There is an urgent need for a Station plant Pathologist who could devote his entire time to this work.

The analysis and inspectional work of the Seed Laboratory has been carried on this year in a very satisfactory way and has received the hearty support of both farmers and seedsmen throughout the State.

Respectfully submitted,

A. K. PEITERSEN,

Botanist

REPORT OF THE CHEMISTRY SECTION

To the Director:

The period covered by this report has been an unfortunate one for the Chemistry section. On the night of December 21-22, 1921, our building was burned out. A temporary roofing was erected and the Chemistry Section proceeded to carry on its work in the improvised laboratory from the spring until about the middle of September, 1922. Of course, all of the arrangements were temporary and crowded, but this was not our greatest inconvenience. The dirt, consequent upon the fire, was very annoying indeed. The delays in obtaining supplies after ordering, were very vexatious indeed. The greatest inconvenience, however, arose from the fact that the notebook that contained the key data to a large portion of the work for 1921 had been destroyed. We had samples of the potatoes of the 1921 crop in cold storage and the work on the tubers could, in a manner, be reported, but the samples of the tops were gone except the dried ones intended for ash determinations. The ashes had to be prepared in these temporary quarters with much danger of contamination by the dust and dirt then prevalent in the building.

The work on the tubers was repeated on the cold storage samples, but it was not very satisfactory. By the middle of June the work of the 1922 season had to be commenced, and that on the 1921 crop was not yet finished. This crowded us very badly. In the meantime, rebuilding operations had begun and the dirt consequent to the tearing out of old walls and the cleaning of brick was very annoying. We had to abandon all work by the middle of September. This permitted us to get the bulk of the work on the green crop and that on the soil done, as well as these circumstances permitted, but we were not able to do anything with the tubers and the dried samples at that time.

Building operations were delayed for good reasons, so that we did not get into the building until February, 1923.

After we got into the building, we had to clean up as best we could, get our supplies in order and take an inventory. This consumed several weeks for the entire force. We found that we had many things to replace and new things to buy. We could not get all of the back work off our hands before the season's work of 1923 had to be begun.

At the end of the period covered by this report, some of the work of 1921 and much of that of 1922 remained incomplete. It may serve to convey to you an idea of the volume of work done by this section to state that for the past five months we have averaged 1040 determinations per month.

In this connection, it is due to my assistants to state that they did not ask for their annual vacation until the work on the 1923 crop was so well advanced that it could be interrupted without detriment.

The section has presented one bulletin entitled "A Peculiar Soil Condition in the San Luis Valley." Besides this, two articles * were prepared for scientific journals which should be credited to this period although one of them did not appear until September, 1923.

We continued our work on the potato crop of the Greeley Station throughout the period in such measure as the circumstances already stated permitted. It is evident from statements made that it will take us a long time to complete the work accumulated. It would be unwise, in my opinion, to leave this work undone. It is necessary to finish the project up to this date, and, however unsatisfactory the results may be, it would be well to complete the work as best we can and file our record for the crops grown.

You ask in your letter for a list of projects upon which we would like to work during the present fiscal year. I have already pointed out the fact that we are so far behind in work partially done that it will be a long while before we have finished it. It will probably be well into May, possibly June, before we can catch up.

You probably do not wish me to discuss the situation at Greeley. Our work there is not co-operative; it is associated with the pathological work of Dr. MacMillan but is really independent. I do not myself think it altogether proper for me, at this juncture, to express my views on the question. Of course, we can continue or quit, there is no co-operative obligation. The uncertainty in regard to how things may develop in this connection leaves me, much to my regret, in a quandary as to what I wish to do. I have no special recommendations to offer.

I wish to officially acknowledge the patience and consideration the section has received during the trying period of homelessness and uncertainty which, unfortunately, still cripples us in some measure.

Respectfully submitted,

WM. P. HEADDEN,

Chemist

REPORT OF ECONOMICS AND SOCIOLOGY SECTION

To the Director:

Five projects received active consideration during the year:

1. Marketing Investigations; in co-operation with the Colorado Division of Markets, State House, Denver, Colo.

2. Settlers' Progress Study; in co-operation with the Division of Land Economics and the Office of Farm Management and Farm Economics, U. S. Department of Agriculture.

3. Cost of Producing Beef Cattle on the Range; in co-operation with Cost of Production, and Farm Management Division, U. S Department of Agriculture.

* Deportment of Calcites toward Radium Radiations—American Journal of Science, Vol. VI, September, 1923

The relation of Composition, Color and Radiation to Luminescence in Calcites. Proceedings of the Colorado Scientific Society, Vol. XI, pp. 399-434, 1923

4. Farm Accounting and Farm Organization; in co-operation with Division of Farm Management and Farm Economics, U. S. Department of Agriculture.

5. Rural Life Studies. Three sub-projects have been taken up under this general heading. One of these was carried in co-operation with the Rural Life section of the Bureau of Agricultural Economics, U. S. Department of Agriculture, Washington, D. C.

It is our plan to continue work with the five major projects listed above during the year 1923-24. A study of the methods of organization, management and results secured through the operation of Colorado co-operative associations is also contemplated. The field of co-operative endeavor is comparatively new in this State. The best interests of these co-operative associations will be served if they can be provided with constructive suggestions with respect to factors that make for success in their business enterprises. In order to know something about what is taking place in our Colorado co-operative associations, active field studies should be initiated and continued through a period of two, three or more years.

Report of Progress on Project No. 1

During the past year information has been assembled regarding some of the more important methods and practices that are employed by Colorado growers in the marketing of fruits and vegetables. This work is being supplemented during the current year with a study of car rejections and the causes for these rejections. It is our plan to combine data collected last year along with the information which will be made available this year and these two phases of our marketing investigations will be presented in a special report.

During the month of August, 1922, approximately 100 farms in the San Luis Valley were visited and information was obtained concerning the methods employed in marketing potatoes in the valley. A brief summary of the results of this investigation were made in a preliminary report.

Report of Progress on Project No. 2

The Settlers' Progress Study which was conducted in co-operation with the Division of Land Economics and the Office of Farm Management and Farm Economics, U. S. Department of Agriculture, was organized and field work was begun in June, 1923. The field work for this project included a study of the farm business for the year 1922. Approximately 80 records were secured in the vicinity of Hugo, in Lincoln County, and essentially the same number was obtained in the vicinity of Akron, Washington County. Along with the farm-business analyses data, suggestions were obtained from these farm operators with reference to the date of settlement and the approximate amount of money and equipment required to begin work in these areas. The records in question have not been worked over sufficiently to enable us to present a detailed report at this time.

Report of Progress on Project No. 3

During the present year some 45 or 50 cost records have been secured from men who are producing beef cattle on the range. It is expected that a preliminary statement will be made available shortly. This will indicate the cost of producing calves under Colorado conditions during the year 1922. A preliminary report on "The Cost and Methods in Carrying Cattle on the National Forest Ranges of Colorado in 1922" has been prepared.

Report of Progress on Project No. 4

Detailed farm accounting records have been kept on some 28 farms in the Greeley area during the past year. These records include complete information with respect to the hours of labor required in handling each farm enterprise; also a complete history of crop production on these farms together with systematic records in regard to current expenses, crop sales and livestock-feeding operations. This investigation will be continued for a sufficient length of time to provide reliable suggestions with reference to changes or modifications in farm organization with the object of securing maximum profits.

Report of Progress on Project No. 5

During the year over 1000 families in a typical small town within a prosperous agricultural district were visited in order to discover how many of these families had lived in the country; where they had lived; why they removed to town; whether they have been satisfied with the change; what they consider the advantages of the city and the country and if they had their lives to live over again would they have moved as shown by this investigation.

During the summer, approximately 100 successful farm families, representing the different farming conditions of the State, were interviewed with the object of finding out just how they have succeeded. Special questions were asked concerning the family; the education of the children, the schools and churches in the district; the economic condition of the farmer and his family; recreation, and their attitude toward the work of operating a farm. The material collected in these two surveys is being tabulated and a detailed report will be made available later.

A special report on Potato Marketing in the San Luis Valley was prepared by Professor R. T. Burdick of this department.

Respectfully submitted,

L. A. MOORHOUSE,

Agricultural Economist

REPORT OF ENTOMOLOGY SECTION

To the Director:

The following is a brief report of the work of the Entomology Section during the fiscal year closing June 30, 1923:

There has been no change in either personnel or projects in this section during the year.

The entomological work from my office as State Entomologist is very closely associated with the investigational work. In fact, some of the men are paid in part from Experiment Station funds, and in part from State Entomologist funds. The life-history and control work with the codling moth and the alfalfa weevil on the Western Slope have continued during the year, but the results of this investigation are published from time to time in State Entomologist circulars.

Following are brief notes on the several projects carried in this section:

Plant-Louse Investigations:

Miss Palmer and the writer have completed a technical paper giving the life habits and descriptions of several new species of Aphids *(Lachninae)* attacking conifers in Colorado. The paper is very fully illustrated and has been accepted for publication in Annals of the Entomological Society of America. This paper more than doubles the number of known species of plant lice attacking the conifers of this State.

Ants of Colorado in their Relation to Plant Lice:

This project is being carried by Professor C. R. Jones, who has made progress in the work during the year, chiefly in adding to the number of species taken in the State and notes concerning their habits as related to the plant lice.

Codling-Moth Studies:

Our studies on the life history and methods of control for this pest to our apple industry have been continued at Grand Junction and in Delta County during the year. We have been especially interested in results obtained in an effort to trap these moths by means of attractive liquids placed in jars in the apple trees. The experiments along this line are to be continued thru another year.

Grasshopper Control:

Mr. C. L. Corkins has continued his experimental work with poisoned baits for the control of grasshoppers, special attention having been given to a very serious outbreak of the Mormon Cricket* in southern Moffat and northern Rio Blanco counties the past spring. While this work was planned and directed from the office of the State Entomologist, I am glad to mention in this connection the great service of Governor Sweet in raising a good contribution in Denver which, with a $2,000 contribution from the Southwestern Division of the American Red Cross, enabled us to put on an effective campaign for the control of the pests in the section where the new settlers would have been unable to raise funds to protect their crops.

* *Anabrus simplex*

General Insect Investigations:

The Potato Flea-beetle *(Epitrix cucumeris)* has been quite destructive again to the potatoes in the Greeley section, and Mr. J. L. Hoerner has been giving considerable of his time to a study of the life habits of this insect, with the hopes of being able to work out better methods of control. Mr. Hoerner has also given some attention to a study of the habits of the false wireworms *(Eleodes sp.)* in the eastern portion of the State, and has made observations upon the extent of the injuries that are being done by them, especially to fall grains, hoping to do some control work later.

The so-called "Alfalfa Eel-worm" has appeared in Fremont County near Canon City, and a single alfalfa crown affected with this same eel-worm was sent to the Station from Walsenburg. This promises to be a rather serious pest to alfalfa and the Station will doubtless be compelled to give some attention to its control in the near future.

Brief mention of a number of injurious insects will be found in the Report of the State Entomologist for the year 1923.

Respectfully submitted,

C. P. GILLETTE,

Entomologist

REPORT OF THE FORESTRY SECTION

To the Director:

Attempts were made toward the close of the last semester of the present year to finish the report upon the project now in force, that of Studies in Timber Decay. It was found impossible, however, due to the summer-camp work in forestry which soon followed commencement. The accumulated data call for intensive work in order to put out the type of report which seems most effective.

A further increase in our teaching schedule under the new four-year course, together with the working up of new courses, will prevent my finishing this report during the present year. It is felt that if any outside work is done it should be in preparing a revision of the State Forestry Publication No. 1, The Evergreens of Colorado. The first edition of this publication is entirely out of print while calls for it are continually increasing. The public schools of the State, especially, are asking for it and its extensive use in this way is regarded as a valuable means of increasing popular forestry knowledge in our State.

Respectfully submitted,

B. O. LONGYEAR

Associate Forester

REPORT OF THE HOME ECONOMICS SECTION

To the Director:

During the year 1922-'23 research was continued on The Cooking Quality of Colorado Potatoes. We obtained potatoes as follows:

a. From the Greeley district: Pearls, of 2-, 4-, 7-, and 11- irrigations; Rurals of 8-, 10-, and 11- irrigations.
b. From Carbondale: Burbanks and Cobblers.
c. From the San Luis Valley: Burbanks

On a certain number of individual tubers of each one of these groups of potatoes, the same rigorous quantitative determinations of moisture, starch, nitrogen and ash, were made as in preceding years. The results of this continued research are now being compiled into a bulletin which it is hoped will be issued this year, 1923-'24.

Research was begun on the Bread-Making Qualities of Colorado Flours. Satisfactory progress was made on this project, which it is hoped to complete during the present academic year, when it is planned to issue a housekeeper's bulletin dealing with the Principles of Bread-Making.

As in other years, the permanent equipment of this section has been added to, always looking towards the ideal of a very completely fitted-up, research, food laboratory.

Attention is respectfully called to the last paragraph of last year's report, in which the needs of excellent library facilities for the research investigator were pointed out.

Respectfully submitted,
N. E. GOLDTHWAITE,
Home Economics Investigations

REPORT OF THE HORTICULTURE SECTION

To the Director:

The following is a brief report on the status of the experimental work carried on by the Horticulture section. The following projects are now in force and will be discussed under project titles:

Head Lettuce:

This work has been in progress for two years at Buena Vista. The object of this work was to aid the farmers in overcoming some of the difficulties that the growers encountered in growing the crop. The newness of the industry made it necessary not only to work on varieties and strains of lettuce best adapted to the mountain conditions of the State but also to work on problems relating to soil fertility, crop rotation, cultural methods and diseases.

The problem of seed, as to variety and strain, has been quite definitely settled.

The problem of soil fertility is a difficult one in the mountain sections. The limited area of land available for this crop makes it difficult to persuade the grower that one should not grow lettuce successively on the same land year after year. Then, too, the soil types are such as to require considerable vegetable matter to keep up the soil conditions, as well as that of fertility. Stable manures are not available in sufficient quantities and it will be necessary to grow and plow under green crops.

The problem of correct cultivation is fairly well established among the better growers, tho considerable difficulty along this line is met with among beginners and among growers who have had little experience and have little knowledge of the effect of cultivation upon the growth of the plant.

In the matter of the plant diseases, considerable difficulty has been encountered, especially with the disease known as tip burn. This problem has been studied in the field and arrangements have been made and are now in progress to study the disease in the greenhouse and in the laboratory, and establish some correlation between the disease and certain constituents in the plant itself. The solution to this problem seems to point to the selection of the resistant strains. This belief is strengthened by the fact that a considerable percentage of the plants in the field are free from the disease. It then resolves itself into a question of selection, which will be carried on for a considerable time to establish disease-resistant strains in seed.

There are also some questions in regard to the proper time of planting the crop. From our work during the last two years, it is evident that Colorado lettuce will reach the highest quality and commercial value during the months of September and October. This means that the planting should be done, starting with the first week in May and continue for two weeks. This will bring the crop on the market during September and October, when there is the greatest demand, and the best prices are obtained.

From our two years of experience in the field we are convinced that head lettuce can be grown successfully in practically all of our mountain sections, at an elevation running from 7500 up to 8000 feet, and even up to 9500 feet.

Like every new industry, it has to pass thru the stage of elimination and thru a state of speculation. While there is a considerable profit in the growing of head lettuce under proper soil, climatic and cultural conditions, there is also considerable to be learned in regard to questions of cultivation, irrigation and planting time, and those who look upon the business in a speculative way are sure to lose money. During the past season the growers have been, on the whole, successful. With a slightly smaller acreage than last year, the shipment or the production has been about three times as great.

In connection with this work, the department is severely handicapped by the lack of experimental land to carry on the work. It is almost impossible to control the various factors in production in doing the

experimental work on land which is rented from some farmer, and there is no security in the matter of continuing the work on the same land for more than one season.

This handicap is more severe when it comes to the exacting requirements of this particular crop.

Tomatoes:

This work was started with the idea in mind to aid in the development of the tomato-canning industry in the State, particularly in the Arkansas Valley. Experiments have shown that the seed or the offspring from the first cross are usually superior in productivity, if not in quality, over their parents. To test out this belief and to inaugurate improved cultural methods, a tract of three acres was leased at Manzanola and the work placed in charge of one of the senior students. Unfortunately, the first planting was entirely destroyed by a heavy hail storm, and a later planting was partially destroyed by flood and what was left perished during a subsequent hail storm, so that no results could be obtained from the work.

High-Altitude Orchard and Small Fruits at Fort Lewis:

Like many of our projects at Fort Lewis, this project has suffered considerably from causes over which we have had no control. The orchard was practically destroyed by mice during the winter of 1922-23 but was, of course, replanted in the spring of 1923. Precautions have now been taken to guard against this trouble in the future: every tree has a wire-netting protector.

The small-fruits work has been, on the whole, successful. Practically every kind of small fruit that can be grown in the North Temperate zone seems to flourish in the altitude of Fort Lewis. The heavy winter snowfalls are rather beneficial to small-fruit plantings, as they afford an excellent winter cover for the planting. The summers are cool, which tends to develop large fruit and fruit of high quality. The small-fruit plantings will be further extended next spring, and with the data we have accumulated a small bulletin on small fruits in high altitudes should be published after a year or two more of work.

Potatoes:

The potato work has, on the whole, been unsatisfactory, insofar as the work on the experimental side is concerned. We are up against the same proposition as we are in the case of head lettuce. Renting or leasing land from a farmer and being dependent upon him for the use of tools and power as well as water for irrigation, makes it almost impossible to carry on experimental work of any value, as the work cannot be performed at the exact time when it should be done.

The problem of disease with which we are now working is an exceedingly complex one, and in order to do effective work, we should have a considerable acreage to permit us to carry on selection of disease-

resistant strains, as we believe that is the only method by which we can hope to cope with the potato diseases in the State. We must also be able to contol the matter of rotation and other features connected with the growing of the crop.

The past year has been one of the most disastrous ones, so far as potato diseases are concerned, that we have experienced in Colorado. Undoubtedly, the climatic conditions during the year were more or less favorable to diseases. Yet, on the whole, we must ascribe the prevalence of diseases to the continued use of poor and diseased seed. The question of seed selection is perhaps the greatest question before our potato growers today. How to carry it across or how to sell this idea to the farmer is difficult to decide, as one cannot get the hearing or the attention of the farmer, unless he is absolutely down and out.

Considerable work has been done in the matter of seed selection and the elimination of diseases, and we have some pure strains but not having the facility to expand we can go no further with this work. The main attention has been centered on the growing of certified seed, and in this connection we are meeting with considerable encouragement from good growers in every part of the State. The number now growing certified seed is, to be sure, somewhat small in comparison with the production of potatoes. Yet we have laid a foundation for this work and it looks promising for the future. Our ideas in regard to the growing of certified seed have undergone some changes during the last two years. We have come to the conclusion that the growing of certified seed is a business for the specialist, the high type of potato grower, and not a business for the average man. We rather look for a reduction in the number of growers of certified seed and to an increase in acreage of those who are most fitted and able to grow the seed. To keep it on that high plane, it will require the high-class grower to enter this line of production.

Vegetables in College Garden:

The vegetable work at the College has been centered on the growing of celery, which is one of the important vegetables grown commercially in the State.

Professor McGinty, who has general charge over vegetable production, is trying out a new strain of lettuce and different cultural methods, and the results are very promising.

A new line of work in the College garden will be that of breeding disease-resistant strains of squash. The ravages from disease on squash have been heavy during the last few years and Professor McGinty is arranging to carry on work in breeding and selecting disease-resistant strains.

Considerable work has been done with the Denia onion, which we have now grown for a period of six years. Two objects are in view: First, the development of a strain of seed that will mature the onions from the seed in the field; second, the development of a type to elimi-

nate scullions and undesirable types of plants in the field of the set onions.

The possibilities of onion culture are not realized in the State. From our experimental plots we have produced as high as 1200 bushels of salable onions to the acre.

Grapes and Variety Test of Fruit Trees on College Farm at Austin:

There is nothing of interest to relate about this work. Extensive plantings were made of many varieties of tree fruits and of grapes last spring. It will be several years before any definite results can be obtained.

Cold Storage:

This project was started four years ago in connection with the horticultural work, and we have the data now from three years of work. It has been written up and is ready for publication, either as an Experiment Station bulletin or as a part of the State Horticulturist's report. I will talk to the director in the near future as to the publication of this project.

Landscape Gardening:

This project is of a more general nature, as we are not in a position to carry on experimental work or work of the type that is usually considered experimental. Yet, there is a distinct field for work caused by the demand for definite information on certain shrubs and trees that are adapted to Colorado conditions; also general information upon the principles of planting and arrangement of the materials into a landscape.

Professor Lowry has accumulated the material for this bulletin and the manuscript is now being prepared and the publication should be printed for distribution by spring.

This concludes in a brief and general way the report of the activities of this section. I wish to make some remarks in regard to the features of the work that we are now undertaking, particularly the work with potatoes and vegetables in high altitudes.

The fruit industry in the State is now well provided for. We have acquired a College experimental fruit farm where problems relating to the industry can be studied to the best advantage. In the case of potatoes and vegetables we are at a loss. The home station is so unfortunately located that the work that can be done is only applicable to general vegetable growing in Northern Colorado. The ground cannot be utilized for the potatoes nor for the vegetables that may be grown in the high altitudes. We are very anxious to place this line on a permanent basis, and the only way that this can be done is to acquire the ownership of land in the mountain section where potatoes and vegetables can be grown, with adequate acreage. This work could yield satisfactory results and we would have a permanent place and would not be continually interfered with by the owner of the land. We wish it were pos-

sible that some money could be set aside for the purchase of such a farm. It need not be expensive. The upkeep as well as all running expenses could be borne by the proceeds from sales, as is the case with our College orchards. It would be, to be sure, the first outlay in the way of the purchase of the land and equipment that would have to be figured as a permanent investment, but I cannot see but what the investment is entirely justified; in fact, I believe that the institution would be greatly benefitted by such an investment, not only from the results obtained from the work but from the support that the College would obtain from all the mountain counties of the State.

Respectfully submitted,

E. P. SANDSTEN,
Horticulturist

REPORT OF IRRIGATION AND DRAINAGE INVESTIGATIONS SECTION

To the Director:

During the past fiscal year, ending June 30, 1923, the work of this section has been confined to the following projects:

Only one Adams Fund project has been under consideration, that of the Venturi Flume. The application of the hydraulic-jump, as developed in a new device, has proved a wonderful improvement in the principle of the Venturi Flume. This improvement was commenced at the close of this fiscal year.

Under the Hatch fund two principal projects have been carried, namely, the Evaporation experiment, and the Measurement of Water as applied in irrigation. The Evaporation studies have been carried in two parts. The observations within the laboratory have been made either under still-air conditions, or under wind conditions of known velocity. The outside condition is under full exposure where the rate of evaporation is carefully determined. The rate of evaporation within and without the laboratory shows very similar characteristics, but the peak or maximum rate does not occur at the same time of day. Within the laboratory, this maximum occurs during the early morning hours, while, outside, the maximum occurs during the afternoon or early evening. The effect of wind is very marked upon the rate of evaporation, observations having been made where the wind velocity has a range from 1.8 to about 11.5 miles per hour. As a usual thing, the data are taken in a series of hourly observations covering a period of approximately 30 hours at intervals of ten days or two weeks. Up to the close of this fiscal year there have been 1328 hourly observations taken within the laboratory, and 258 outside since June, 1920.

At the Bellvue laboratory a series of observations was made on the Herschel Hollow-Crest Weir for the purpose of determining its practic-

ability as an irrigation device. This structure consists of a hollow crest (tubular) set in a horizontal position, where the floor of the approach section rises at a slope of 2:1 to the crest level and then is depressed at this same slope beyond the crest. The sides of the structure are parallel and vertical. Two pressure heads were observed; one at a point upstream from the crest and the other at the crest, the latter being a negative value. One striking feature of this device is the fact that the discharge is directly proportional to the difference in value of these two heads. Various settings concerning contractions were investigated. It was found that by eliminating the sloping upper bottom contraction and flaring the sides of the approach section, but still confining the stream downstream from the crest by parallel vertical sides,, the device then possessed certain characteristics which were of practical importance. This modified design now eliminates the hollow crest.

A series of calibrations was made using this modified design, but instead of permitting the water to fall indefinitely down the 2:1 slope from the crest, a reverse slope of 6:1 was installed, which led the discharging current upward to an elevation one-half foot below the crest elevation at a point five feet down stream from the crest. Such a device possessed the remarkable characteristic of withstanding a submergence of practically 75 percent before the free flow condition is materially affected.

Because of the extreme low-water conditions of the river during the late summer and fall, work at the Bellvue laboratory was discontinued early in September. This new device was then installed at the Fort Collins laboratory, where 1, 1½, 2 and 3-foot widths of structure were calibrated, but with discharges limited to about 16 second feet, the capacity of the laboratory. The results obtained at the Fort Collins laboratory show very consistent relations thruout the range of discharge investigated. For free-flow discharge, with a minimum head of 0.3 foot and maximum head of 1.4 feet on the 1, 1½ and 2-foot flumes, and 1.0 foot on the 3-foot flume with discharges from 0.5 second-foot to 16 second-feet, the mean computed deviation from the curve was 0.8 percent. The free flow discharge formula is

$$Q = (4.66W - 0.23)\ H^{1.65}$$

where Q is second-feet, W width of flume and H the upper head in feet.

The Bellvue laboratory was originally built in the fall of 1919, when a flume 10 feet wide and 60 feet long was constructed of framed timber with a concrete floor. The season of 1922 found this flume in bad condition, and because of the economic importance of this field laboratory, as well as with the sincere and cordial co-operation of the Jackson Ditch Company, it was decided to replace the wooden structure with substantial concrete construction. The building of the two walls forming the flume and the laying of another floor cost $500. The small office building and protecting stone wall cost about $400. These improvements have been decidedly worth while and have now made possible the investigation of irrigation structures of practical size. The

maximum discharge available at this laboratory is about 100 second-feet, some six times the capacity of the Fort Collins laboratory, and the size of the flume, which is 14 feet wide and 5½ feet deep, is sufficient to accommodate test structures of actual dimension such as would be found in practical application. This Bellvue laboratory has made possible the further investigation of the new-type flume, as previously mentioned, to a width of 10 feet and a discharge of about 60 second-feet. The development of this new type of measuring device is an important step in the advancement of the science of measuring flowing water, both for power and irrigation purposes, and it is felt that the facilities provided at Bellvue, which permit the study of this new device under practical sizes, have amply repaid the time and expense incurred in establishing this important feature of our experimental work.

Under State funds the projects in Meteorology and the Arkansas Valley investigations have been carried during the past fiscal year. The work in Meteorology has been a continuation of that in past years, consisting in the observation of meteorological conditions twice daily, the posting of weather bulletins each day, and the publishing in local papers of the weather report. Sufficient data are now avaliable for the publication of a revised edition of Colorado Climatology, which will be brought out during the fiscal year of 1924.

The Arkansas Valley Investigation has been actively pursued during the year. The general outline followed is similar to that of last year. The several farms selected for special study in the Duty of Water have all been maintained except one at Fowler. Because of difficulty with the measurement of water on this farm, it was thought advisable to abandon it and we were successful in substituting another in the same vicinity. Due to the variation in the soil type of the valley, a series of observations has been made to determine the water-holding capacity of the soil, these soil investigations having been made at Fowler, Rocky Ford, Las Animas, Wiley and Lamar. A basin 12 feet square was constructed and a known quantity of water applied to this area. Soil samples were taken previous to the test for the purpose of determining the percentage of moisture at 1-foot intervals to a depth of 6 feet. After the application of the water, other samples were taken at various intervals to obtain the rate of percolation downward thru the soil column and ultimately to determine what portion of the water applied in irrigation was lost beyond the root zone, and also to ascertain the economic application as well as the interval between irrigations.

The results obtained during the season of 1922 on the experimental plots of the farm of the American Beet Sugar Company did not show any marked effect of the amount of water applied in irrigation to the yield in crop. In general, the more water applied the greater the tonnage of sugar beets; the percent of sugar reached a maximum at about 1-acre-foot per acre application; but no direct relation appears between amount of irrigation and purity. The yield of sugar in pounds per acre was greatest for an application of 3 acre-feet per acre. For the eight-

een 1-acre plots under study, the yield in sugar per acre was directly proportional to the niter content of the soil.

The special farms in the valley under observation concerning Duty of Water show a rather wide variation, ranging from a duty of 0.77 acre-foot to 2.34 acre-feet, with an average duty on the several farms, for all crops, of 1.50 acre-feet per acre.

Attention has been given to general work thruout the State pertaining to special assignments, such as assistance in the organization of drainage districts, and advice and assistance to farmers in their measurements-of-water problems, as well as the investigation of conditions having to do with general irrigation conditions of the State.

Respectfully submitted,
RALPH PARSHALL,
Senior Irrigation Engineer

REPORT OF THE VETERINARY SECTION

To the Director:

Most of the work in Animal-Disease investigation is carried on in the Pathology Section. In the Veterinary Section there is but one general project, Animal Diseases.

During the present year there has been no disease among animals in Colorado which has assumed anything like epizootic proportions, save possibly, hog cholera. This disease comes in cyles, and as was expected there has been more cholera than for several years.

The State is well organized to control contagious diseases. The office of State Veterinarian in Denver has regulatory supervision in such cases. We have benefitted by Federal co-operation in the control of mange and scab for several years. Furthermore, a veterinarian under the auspices of the Bureau of Animal Industry, has been placed in Colorado, with the title of Hog Cholera Specialist, who has been given a wide range of service in the control of all infectious and contagious diseases. Lastly, the veterinarians of the department co-operate to the fullest extent, but more especially along the line of investigations under approved projects.

There have been no changes in the staff of the Veterinary Section during the last year and no important addition has been made to the equipment.

Respectfully submitted,
GEO. H. GLOVER,
Veterinarian

REPORT OF THE ENGINEERING DIVISION

To the Director:

I am transmitting herewith the reports of the Civil Engineering and of the Mechanical Engineering Sections of the Experiment Station.

The Civil Engineering Section has been devoting practically all of its time to carrying out the co-operative agreement between the Station and the State Highway Department, and much valuable information is being gathered concerning the road materials of Colorado.

The Mechanical Engineering Section has completed two projects and is now at work on two others.

Respectfully submitted,
LD CRAIN,
Vice-Director

REPORT OF THE MECHANICAL ENGINEERING SECTION

To the Chairman, Engineering Division:

The projects upon which the Mechanical Engineering Section has been engaged during the last Federal fiscal year are: (1) Methods of Handling Hay in Colorado; (2) Heat Transmission of Commercial Wall Board; (3) Treatment of Alkali and Other Waters for Domestic Use; (4) Testing of Lubricating Oils.

The investigational work on the projects, Methods of Handling Hay in Colorado, and Heat Transmission of Commercial Wall Board, was completed during the fiscal year 1921-22, but the publication of a popular bulletin on each of the above mentioned projects was done during the past fiscal year. Neither of the two remaining projects have been completed. The investigational work has been done by the writer who is spending full time in this section.

The greater part of the present fiscal year will be given to the completion of the projects—Treatment of Alkali and Other Waters for Domestic Use, and Testing of Lubricating Oils. We would like to prosecute work during the present fiscal year on "A Comparison of Domestic Heating Plants," if proper arrangements can be made. This work will be under my immediate supervision.

Respectfully submitted,
G. A. CUMMINGS,
Investigator

REPORT OF THE CIVIL ENGINEERING SECTION

To the Chairman, Engineering Division:

The experimental work in this section is carried on by Mr. O. V. Adams.

Mr. Adams is doing experimental work upon Road Materials of Colorado in conjunction with the State Highway Department of Colorado. A preliminary report on this work was issued in April of this year, entitled "Report of Road Materials Project, Part I." Mr. Adams is temporarily on leave, his place being taken by Mr. Donald L. Jones.

The report of the work in the Road Materials Laboratory is fully covered by the men in charge. A brief report by Mr. Jones follows:

"To E. B. House, Civil Engineer:

"In this section the only project carried during the year has been that on Road Materials of the State.

"The co-operative agreement between the State Highway Department and this section, made in 1921, has, by mutual understanding, remained in force. The organization has consisted of a field party of two men; the foreman being furnished by the State Highway Department, and the assistant by this section. The work in the laboratory has been carried on with the aid of an assistant on part time, and with student labor.

"During the period covered by this report the laboratory has tested materials from 241 pits which were located by the field party. A total of 302 samples have been tested up to this time since December 1, 1922. Since September 15, the field party has consisted of but one man, the assistant being taken off at that time.

"A progress report of the work done in this section was published, April, 1923, and contains the reports of all samples up to December 1, 1922.

"The investigation to determine the effect of beet pulp upon mortar and concrete has been completed insofar as the storing period is concerned, and the testing completed. The data on this investigation have not, as yet, been compiled."

Respectfully submitted,

E. B. HOUSE,
Civil Engineer.

REPORT OF THE EDITOR OF PUBLICATIONS

To the Director:

I am submitting herewith a brief report of the work done by this office for the Colorado Experiment Station for the fiscal year 1922-23.

In addition to the regular run of bulletins, considerable publicity has been secured through the newspapers and magazines of the State during the past year.

Following is a complete list of the Station publications passing through this office:

Three more bulletin manuscripts are now in the hands of the printer and should be ready for distribution within a very short time.

Bulletin No.	Title and Author	Pages	Edition
278	Degeneration in Colorado Potatoes, E. P. Sandsten and C. Milton Tompkins	15	3000
279	Return of Seepage Water to the Lower South Platte River, Ralph L. Parshall	72	2500
280	Sodium Arsenite as a Killing Agent in Grasshopper Baits, C. L. Corkins	15	3000
281	Methods of Handling Hay in Colorado, G. A. Cumings	39	4000
282	Heat Transmission of Commercial Wallboard, G. A. Cummings	8	2000
283	Head Lettuce in Colorado, R. A. McGinty	26	4000
284	Report of Road Materials Project, Part I., O. V. Adams	46	1500
285	Control of the Whorled Milkweed in Colorado, W. L. May	24	3000
286	A Peculiar Soil Condition in the San Luis Valley, Wm. P. Headden	15	1500
	Report		
	Thirty-Fifth Annual Report	30	1500
	Total	290	26000

Respectfully submitted,

I. G. KINGHORN,
Editor of Publications

ANNUAL REPORT OF THE VETERINARY PATHOLOGY SECTION

To the Director:

PROJECTS IN FORCE:

I. Sheep Losses in the Feedlots.
II. Contagious Abortion.
III. General.

Projects in Abeyance:

Forage Poisoning in Horses.

I. SHEEP LOSSES:

Work on this project during the last feeding season was largely concerned with excessive losses associated with a heavy grain feeding. Lambs that were being fattened for market, on receiving 1 to 1½ lbs. corn, died in considerable numbers, in many cases without particular preliminary symptoms. Where symptoms were observed, scouring was noticed and a cerebral disturbance which was evidenced by throwing the head back toward the shoulders. In many bands 2 to 4 percent were lost from this trouble. It appeared that the lambs which were most vigorous and in the best condition of flesh were those most likely to be attacked. A large number of animal inoculations failed to reveal any organism which could be held responsible for the trouble. Neither aerobic nor anaerobic cultures gave any indications of the cause. In all cases observed by us where the grain was removed for as much as three days, the lambs stopped dying immediately. However, when the same lot was again brot up to 1 or 1½ lbs. corn per day the disease, in many instances, manifested itself again and with considerable loss. It seemed difficult to feed a sufficient ration to fatten the lambs and at the same time not cause death. It seemed, from this, reasonable to assume that the malady was in some way associated with the high feeding of corn, although we were not able to demonstrate any particularly poisonous principles in this concentrate. Further work is being continued on this trouble as it seems to be of the same nature as that which has been observed in the San Luis Valley for many years.

San Luis Valley:

During the year we finished the second feeding experiment in the San Luis Valley with results which seemed to point in the same direction as our previous findings;—that the real problem was to work out a satisfactory method of feeding peas. Since it seemed to be a question of proper variety of ration, we felt that the Animal Husbandry Section was better able to handle the matter than we, and as a consequence, have turned the project over to that section retaining interest in it only in an advisory and co-operative capacity. There is reason to hope that peas can be used for food for lambs if fed in proper mixture with other foods.

Hemmorrhagic Septicemia:

Only a few outbreaks of this disease have been observed during the year, so that little further information has been obtained. A paper appeared by the writer in the Journal of the A. V. M. A. entitled, "An Outbreak of Hemorrhagic Septicemia in Sheep," Vol. 62, Page 759. In this outbreak we were able to show that the organism was present in 32 out of 34 animals examined.

The work on determination of strains of the organism causing Hemorrhagic Septicemia in sheep has been continued but is not yet ready for publication.

Ictero Hematuria:

Ticks were obtained from sheep in the region of Craig, Colo., where *Ictero Hematuria* is known to exist and brought to Fort Collins where they were placed on experimental animals. While they fastened onto the animals for a time nothing has developed which would indicate that the disease was thereby transmitted. This disease still remains an enigma.

II. CONTAGIOUS ABORTION

Our work to determine the value of the live organism vaccine in beef animals has been continued, but, owing to some failure on the part of co-operating parties, we have been unable to obtain as much information as we would have desired. However the work is being pushed as rapidly as possible, and is being closely checked by agglutination tests, so that it is hoped information may be added over a series of years which will prove of value.

FORAGE POISONING

The work on this project has been held in abeyance for the reason that no field cases have developed..

In view of the fact that the teaching in the department has required more attention it seemed to be desirable to transfer Dr. Feldman to teaching work for most of his time, expecting him to give only his summer to the investigational side. This made is necessary to employ someone who could take some of the routine work off of Dr. Cross. Accordingly, Miss Beulah Malone has been employed for this purpose. She is giving half time to investigational work and half to the instructional side. Dr. Cross continues to carry the larger proportion of the investigational work and is becoming more and more efficient.

Respectfully submitted,

I. E. NEWSOM, Pathologist

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The Colorado Experiment Station
AGRICULTURAL DIVISION

BEAUTIFYING THE HOME GROUNDS

FOR THE SMALLER TYPE

By E. Monroe Lowry



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COLORADO AGRICULTURAL COLLEGE
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BEAUTIFYING THE HOME GROUNDS

FOR THE SMALLER TYPE

By E. Monroe Lowry

For years and even centuries of the past the attention of the landscape architects and gardeners has been directed toward the private estate developments and civic-improvement needs of the larger cities. The countless number of small-home owners, both urban and rural, have been left to solve their problems alone and without careful instruction. Those who have made the attempt should be commended for their efforts. They have done well, considering the fact that very little has been written or spoken to which they might refer or be guided in applying style to the development. With this condition in mind, it is the purpose of the writer to give helpful suggestions to the small-home owner of moderate means who may be desirous of beautifying his or her home along the most up-to-date and economical arrangements possible.

The time has come when style in home beautifying is a noticeable and essential factor. There are right and wrong ways of developing the home grounds and it is in most instances just as easy and cheap to do the job right to begin with and far more attractive to all concerned. We recognize the fact that each home presents a different problem and on account of existing circumstances it may not be possible to follow all the instructions given here. However, they will serve as a guide and should be approached as nearly as conditions will permit. The important principles involved are after all very few, but they are of so much importance that care should be exercised in making the proper use of each. When this is done the home will have that charm and attractiveness that continues to grow dearer to the home-owner and wins admiration from all who come in contact with it.

TYPE OF DEVELOPMENT FOR COLORADO

Here in Colorado with all our natural mountain scenery we believe it best to design our home grounds with as much of that touch of naturalness as can well be developed. It is well where possible to avoid straight and architecturally laid out rows of trees or shrubs, and plant them in irregular groups or masses with open lawn areas intervening. Where there is room, the walks and drives may enter on slight curves instead of staight lines. This is hardly practicable on a small city lot such as is shown in Plate I. Where such straight lines as this occur, and around the base of the house, groupings of shrubs or trees may be placed in such a way as to break up the appearance of formality. Where it is desired to have flowers we advise setting aside a certain, definite, secluded area for them such as is more fully described

under the discussion of the flower garden. This is much to be preferred over the original custom of making an architecturally designed bed in a conspicuous place in the front yard.

The more closely one approaches the natural type of home beautifying the less will be the expense involved in developing it and maintaining the landscape after it is developed. Of course, any attempt however simple must receive continued care and up-keep in order to present the most pleasing appearance. By carefully studying the different illustrations shown in this bulletin one can gain a fair knowledge of the principles involved in the lay-out of the informal developments such as are recommended for Colorado homes.

LOCATION OF HOUSE AND GARAGE

The first principle of home beautifying concerns itself with the location of the house and garage. In order to carry out a satisfactory planting plan, the house on a small city lot should have a set-back line (distance between the inside edge of the sidewalk and the foremost building line of the house) of not less than twenty-five feet. In the case of large suburban and country homes the set-back line should increase proportionately to the area to be developed. Let us hope that the time is not far distant when our cities and villages will prohibit the subdividing of residential tracts into the customary small lots of the past, and that ordinances will be enforced compelling all residences to have a set-back line of twenty feet or more. The width of the house should not exceed more than three-fifths of the width of the lot it occupies and more sideyard space than that is much to be desired. This statement should not lead one to form the impression that the house should be located in the center of the lot. As a matter of fact, it is generally advisable to locate the house slightly to one side of center.

In locating the garage, do not place it in front of the house in the set-back line area such as is often done in some of the larger cities. Its place is in the rear of the house and it is best to have it located to one side of the driveway so that it may be entered at an angle, rather than be a direct terminus for a stright drive. It is then best wholly or partially screened from the street by plantings of trees and shrubs or vine covered arbors or pergolas. This arrangement is not always permissible but quite desirable.

DRIVES AND WALKS

In the case of the small city lot it is quite difficult to do otherwise than enter the premises with straight walks and garage entrances. If convenient to do so, it would be advantageous from the landscape point of view to enter the garage from the alley in the rear. This would leave more of the front yard to be devoted to lawn and thus make it more attractive. Where this is not feasible, it is sometimes possible for a partnership drive to be erected on the line between two lots, which will answer the need of two families, instead of one. Then again, in



Plate No. 1.—STRAIGHT ENTRANCE DRIVE
This method is much to be preferred over the solid cement entrance.

the case of the shorter straight drive, it is advisable to have a two-tread entrance such as is illustrated in Plate No. 1. The intervening grass helps to break up the monotony of an otherwise solid driveway.

,, Where drive and walk both enter the small lot from the front they should not enter near each other on parallel lines. A better solution of the problem is shown in Plates 1 and 8 where one tread of the drive is used for the public entrance or service walk.

In entering the larger suburban or rural residence grounds, there is much more chance for variety in locating the entrances. The following precautions and suggestions should be considered:

Try to avoid bisecting the open lawn in front of the house. Better enter near one side.

Introduce a curve if convenient, but where a bend is made make an apparent reason for it by planting trees or shrubs or both.

Enter the property and end the drive or walk at right angles. The curve comes between. This is illustrated in Plate No. 2.

The corner entrance is objectionable. Leave a few feet between the corner and the entrance.

Other material such as cinders, gravel, crushed rock and brick



Plate No. 2.—CURVED ENTRANCE DRIVE
Where it can be done, this is much to be preferred over the straight entrance. Notice it enters at right angles to the street, curves inside the property line and disappears from view.

often make a more desirable driveway than cement. Any dull color the driveway or walk may have will harmonize better with the lawn which it traverses.

Where a rear walk is seldom used it is often advisable to use stepping stones laid level with the surface of the lawn. They answer the purpose and are not as conspicuous as a solid walk.

Use no more walks or drives than are absolutely necessary.

AREAS

The well-designed lot will be more or less divided into three fairly well-defined areas: the public, private and service.

The public area is that portion of the yard lying between the house and street. As the term implies, it is developed for the passing public to enjoy. The lawn directly in front of the residence is best left open. Shrubs planted on each side of the walk or driveway entrances, along the property line on each side and against the foundation and porch of the house are to be encouraged. The public area should be separated from the rear of the property by some carefully arranged placing of lattice work or shrubs, or both. Plates 3 and 4 show a good arangement of the public area.



Plate No. 3.—THE PUBLIC AREA
The walk enters at the side and does not bisect the open front lawn.



Plate No. 4.—THE PUBLIC AREA
Showing a splendid grouping of trees and shrubs about the residence.



Plate No. 5.—PRIVATE AREA TREATED FORMALLY

Enclosed with a hedge, having balance and symetry and architectural garden features. The vine-covered arbor makes a good terminus for the central walk or axis. An area of this kind affords splendid opportunities for any desired flower beds.

The private area should always be provided for. It is located at the side and to the rear of the house. It is here that the family and friends can enjoy privacy out of doors. It is generally surrounded by a boundary of shrubs and trees of sufficient height to shut out the views of the neighborhood. It is made of any desirable size, according to the needs and area available for its use. Where there is room this area may be subdivided into the private area for family use and outdoor evening parties, the children's playground and the formal flower garden. These are more or less distinct areas and yet all connected in a unit of composition. Shrubs properly arranged and grouped as illustrated in Plates 5 and 6 will give this effect. These units may and should be provided with garden accessories and comforts appropriate to the needs of each.

The informal family and evening-party area can be provided with such features as a tea house, arbors, arched seats, lawn swings, lily and fish pools, rockery work, sun dials, bird baths, gazing globes and many forms of rustic work.

The children's playground should be equipped with such features as sand boxes, wading pools, shoot the chutes, swings, teeters, play

houses, bars, rings, or others of like character according to the needs and ability to provide them.

So far we have been speaking of the informal arrangement of the landscape, and no mention has been made of flowers. We now undertake a discussion of the formal flower garden as the third subdivision of the private area. Nearly every family desires to have flower beds and, as mentioned before, the tendency has always been to scatter them promiscuously over the yard, in the center of wide open lawns or as borders around the house and along the walks and drives. It is now considered much better form to provide a regular area for them and confine all flowers to this area. Because of their very conspicuous, bright colors, they belong in beds of architectural design and do not go well with the more sombre hues of an informal development of natural lawn, trees and shrubs. It is extremely hard to do this without breaking up the naturalness.

We now believe the formal garden should be made a part of every development where flowers are to be introduced at all. This garden is best enclosed by a trimmed hedge or a vine-covered fence of some description with a square or rectangular shape. Inside of this all flower



Plate No. 6.—THE PRIVATE AREA TREATED INFORMALLY

Passing through the rose-covered arch, the visitor is led into another area of a more informal type. The planting in the background adds a touch of naturalness and a feeling of privacy.



Plate No. 7.—FOUNDATION PLANTING FOR THE LOW RESIDENCE

A good combination of planting materials which ties the building into the lawn in a pleasing manner. Slightly over-planted.

beds are laid out in definite designs and figures, with walks of grass, brick or gravel as one may desire. The walks are probably best introduced as a definite axis and cross axis of the garden, with some terminating feature to balance in the center and at the ends. Pergolas, fountains, gazing globes, pools, sun dials, seats, arches, odd-trimmed trees, or statuary work may be added to the formal garden. From the inside it should present a strictly architectural arrangement, with the hedge or fence enclosing it. The height of the hedge should correspond to the size of the area it encloses, else it will be lacking in proportion. Irregular masses of shrubs or trees are massed on the outside of the formal garden in such a way as to break up somewhat all straight lines when viewed from the informal areas surrounding. When walking through the surrounding yard one should not be led to realize that the formal garden was present until an entrance was actually made into it.

Such features as the vegetable and fruit garden, garage, ash can, laundry line, or other useful and necessary additions to the landscape should, where possible, be grouped near each other in a more or less separate portion of the development and adjacent to the kitchen. This, as a unit, we call the service area. Sometimes the vegetable garden is made a thing of esthetic attractiveness as well as of usefulness, by the introduction of grass walks, with vine-covered lattice or wire fences surrounding it. Again, this area may be developed in connection with the formal flower garden, in such a way as to make both an attraction during the entire season.

STEPS INVOLVED IN THE UNDERTAKING

First, make up your mind that you are going to do the job right, even tho it has to be done in piecemeals or a little each year. You should have a definite plan worked out on paper showing every proposed detail. Know where every shrub, vine and tree is to be located and the kind and number needed of each. Show the proposed location of all lawn areas, the formal flower garden and all garden features. Where one can afford to do so, it is best to have a trained landscape architect draw up the plan and furnish a planting plan showing the kind and location of all plant materials. However, this is not always possible and the amateur can have a chance to develop his or her own ideas which are often very good. This plan should be completed far in advance of the planting season and from it one can determine the number of plant materials needed.



Plate No. 8.—THE SMALL CITY LOT

This plan shows only one of many possible developments for a lot 60x150 feet. The public area in front is open and unbroken. The private area is subdivided into two parts to the left and back of the house, aside from the flower garden. The service area is unified to the right and back of the house. A plan similar to this should be drawn upon paper during the winter months.

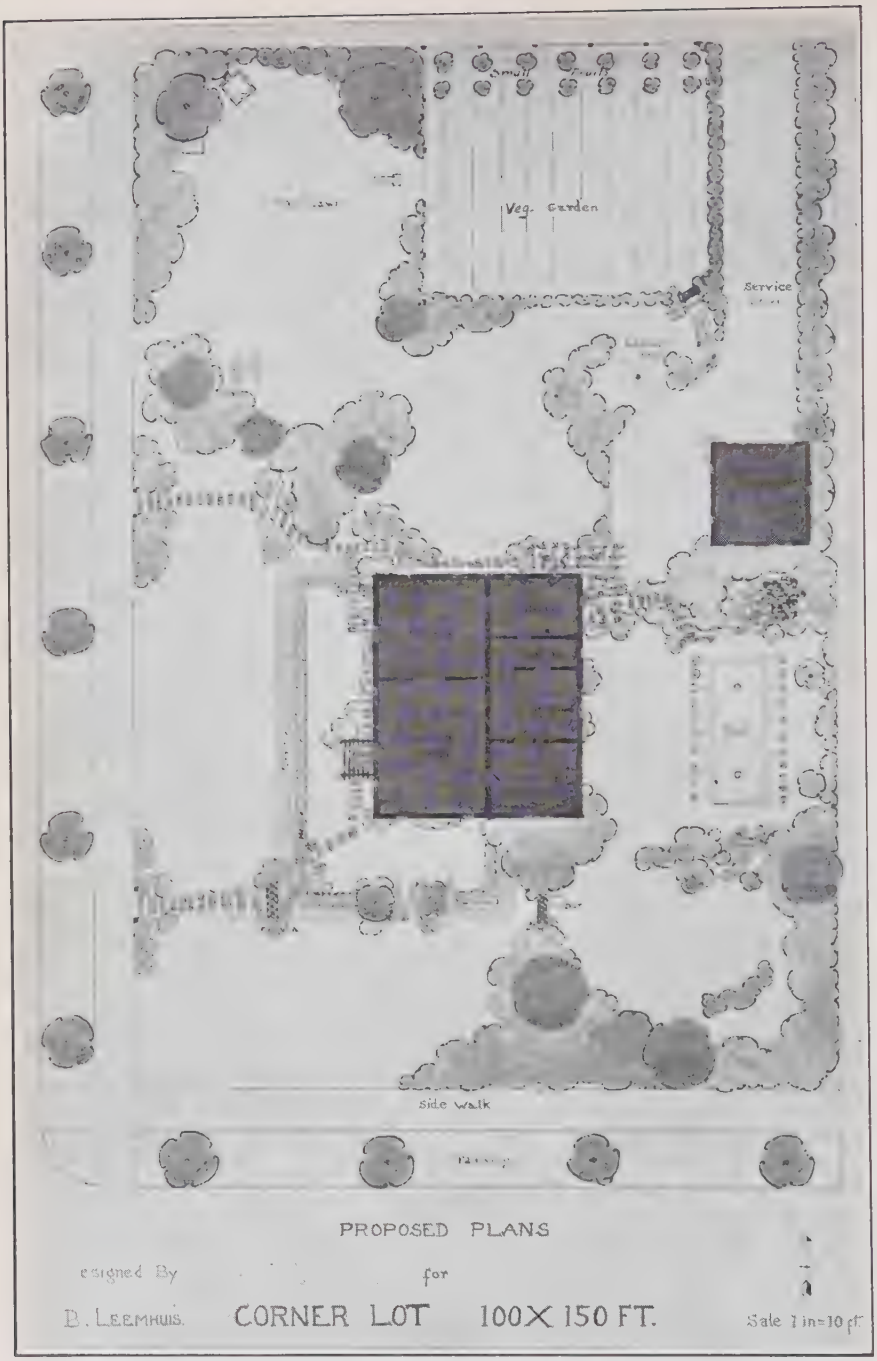


Plate No. 9—THE DOUBLE LOT OR SUBURBAN DEVELOPMENT
The larger the yard the more opportunities for variety and privacy. Here the three areas are also well treated. A one-and-one-half or two-story house would harmonize well to this size of lot. Note the privacy that would result from an arrangement of this kind.

MAKING THE LAWN

A good lawn is the most important and attractive feature of the landscape. It takes a first-class soil, careful attention and two or more years to get a good turf. Some people have the erroneous idea that a good lawn will grow anywhere. Often the subsoil from a basement is dragged out into the yard and later sown to lawn grass without any top dressing. Later the grass becomes stunted, is hard to keep sufficiently watered and never gives a luxuriant growth or a good turf. The soil for a good lawn should be just as rich, and just as deep as if planted to vegetables. It is best to have a gentle slope leading away from the house rather than have it level. Pulverize all clods, roll with a heavy lawn roller, rake and then roll and rake a second time. If the ground is of a desirable character for a good lawn, it will not hurt to have it firmed down quite compactly. The best time to sow the lawn is early in spring. However, if given strict attention, a lawn may be secured at any time during the summer or early fall. If sown in the heat of the summer, the soil should be sprinkled once or twice each day in order to keep it from drying out during the germination period. Often it is advisable to scatter a light coat of well-rotted and pulverized compost or manure over the soil after the seed has been sown. This helps to hold the moisture and adds more fertility for the grass roots to feed upon.

One should procure the best seed possible, in order to avoid obnoxious grasses that often result from the sowing of poor seed procured at the local stores. The seed should be ordered in advance from the most reliable seed houses in the country. The lawn grass mixtures ready for planting are to be advised unless one only desires a simple lawn of blue grass and white clover. In such a case, 8 parts of the former to one of the latter is generally satisfactory.

In using the ready-mixed seed, one should allow one pound for each 200 square feet. Before sowing, divide the required amount into two equal parts. Sow one half one way of the lawn and the other half the reverse way. It should be sown when there is no wind, preferably early in the morning or late in the afternoon. The width of the swathe may be regulated by setting stakes, stretching strings or marking off the rows. After the seed is sown the soil should be lightly raked and if it has not been thoroly worked and rolled beforehand, it should be rolled afterward. Sprinkle with a fine spray of water from the nozzle, being careful to keep the water from running long enough in one place to cause any washing away of the soil. If a terrace is to be grassed, it is much better to secure sod to use for the purpose on account of it being so difficult to water without washing the seed away. Do not neglect the watering at any time during the period of germination.

Never be in a hurry to mow the grass the first time, and then adjust the machine so it will cut the grass longer than usual.

Most lawns need to be fertilized every two or three years. Barnyard manure applied evenly over the lawn early in the winter and allowed to remain on the grass as long as possible in the spring is the



Plate No. 10.—FOUNDATION PLANTING FOR THE TALL RESIDENCE

This type of building requires a much taller grouping of shrubs and trees. Note how well the straight lines of the building are broken up.

general method used. Only rake off the coarsest of the mulch at that time. As a rule, commercial fertilizers should not be used as long as the animal manures are available.

TREES AND SHRUBS

Having previously prepared a plan of the proposed development, one should be able to determine the number and kind of trees and shrubs desired to plant the landscape. The order for these should be placed early in the season with instructions to ship as soon in the spring as it is usually possible to work the ground. Generally speaking, the earlier the plant materials can be set the less loss will be encountered. It is usually best to get the shrubs and trees set before sowing the lawn although there are times when this cannot be done. Several of the native trees and shrubs do very well when set in the lawn and often the expense of planting materials can be greatly reduced by their use.

In mass planting, do not set plants at regular distances apart. On the whole it is better to have them set too close rather than too far part. Set them slightly deeper than they stood in the nursery. Tramp the dirt firmly about the roots and water thoroughly at the time of setting.

First of all, abandon the idea of planting trees or shrubs in straight lines, excepting where a hedge is desired, or in the case of trees along

the street or highway where they must be planted in rows. In the yard try to imitate nature and plant them in groups of irregular outline. In attempting to do this there are a few important factors to be considered.

First we need variety. In any group of three or more specimen plants, it is generally advisable to have two or more varieties or species introduced. The number of different kinds used would depend upon the size of the group planted. Care should be exercised, however, in not having too many kinds mixed together in a single group.

Variety in size is also important. In selecting plants for a group it is necessary to know the approximate height the specimens will attain when full grown. Then by mixing species that grow at different heights we get an irregular contour effect that is much to be preferred over a flat surface. One should attempt to gain accent by planting the tallest varieties against a wall or fence with the shorter ones in front. Or in case of the group that is planted so that it can be approached from all sides, the tallest should be planted in the center with the shorter all around. By referring to the several photographic illustrations, one will understand what we mean by variety in size.

Then again, we should look for variety in color of the flowers, bark and leaves. Too many flowers of one color blooming at the same time appear monotonous. Know the blooming period and the color of blossoms and try to get variety and yet a pleasing contrast and satisfactory blending.



Plate No. 11.—PERGOLA

An architecturally designed garden feature, as shown here, rightly belongs in the formal garden. The more simple, rustic, vine-covered arbor goes better in the informal area. In either case, it should be backed up with trees or shrubs and not located out in the open lawn.



Plate No.12.—THE GAZING GLOBE

This interesting feature should be located where the best view of the surrounding landscape can be portrayed thereon. In connection with the seat it should be criticised as being of too conspicuous a color to harmonize with the natural surroundings.

Certain evergreens blend well with some of the deciduous shrubs and trees, giving variety in color and improved winter effects. Especially is this true when we use spruce and firs in the planting. Some shrubs like the dogwoods and willows have conspicuous colored bark and add a great deal of variety to the group.

Trees give the best results when planted mainly to the side and back of the residence. In this way they give the desired shade and also make a much better setting for the house.

Shrubs, as has already been stated, are used for separating one area from the other and are also used for breaking up any straight lines caused by fences, walks, drives and buildings. They also serve a useful purpose in screening unsightly objects from view.

Probably one of the most essential uses of shrubs is where they are used as a foundation planting around the house or other buildings. Here they serve the purpose of breaking up the straight lines caused by the building and tie the house into the lawn more satisfactorily. The height of the house will determine to a great extent the height of the shrubs that are to be used. A continuous planting should not be made, but rather set in groups with open spaces between so that an occasional glimpse of the foundation is observed. Plant specimens that will vary in height when grown and have some groups swell out farther from the house than others, so as to avoid the sense of regularity. Plates No. 7 and 10 show a good use of shrubs for foundation planting.

RECOMMENDED PLANT LIST FOR COLORADO CONDITIONS

Deciduous Street Trees

Ulmus fulva	Slippery or red elm
Ulmus Americana	American white elm
Acer platanoides	Norway maple
Fraxinus Americana	American white ash
Fraxinus lanceolata	Green Ash
Tilia Americana	American linden or basswood

Deciduous Lawn Trees

All of the above street trees plus

Celtis occidentalis	Hackberry
Aesculus hippocastanum	Horse Chestnut
Sorbus aucuparia	European mountain ash
Betula populifolia	American white birch
Catalpa speciosa	Western catalpa
Larix decidua	European larch.

Hardy Evergreen Trees

Juniperus scopulorum	Rocky Mountain red cedar
Pinus sylvestris	Scotch pine
Picea pungens, var. glauca	Colorado blue spruce
Picea canadensis	Black Hills spruce
Abies concolor	White fir
Picea Englemanni	Engleman spruce

Deciduous Hardy Shrubs

		Height
Berberis Thunbergii	Thunberg's Barberry	3-5 feet
Shepherdia argentea	Buffalo berry	5-8 feet
Cornus alba siberica	Red dogwood	8-15 feet
Lonicera tartarica	Tartarian honeysuckle	6-9 feet
Viburnum opulus	High bush cranberry	6-8 feet
Virburnum opulus steriles	Common snowball	6-8 feet
Ribes aureum	Wild currant	4-6 feet
Syringa	Lilac-white, purple—Rouen	6-10 feet
Philadelphus coronarius	Mock orange	5-8 feet
Tamarix	Tamarisk	5-8 feet
Ligustrum armurense	Amoor river privet (for hedge)	3-6 feet
Garagana arborescens	Siberian pea tree	5-8 feet
Spirea Van Houttei	Bridal wreath	4-6 feet
Spirea Billardi	Billiards spirea	3-5 feet
Spirea Anthony Waterer		3-4 feet
Symphoricarpos racemosus	Snowberry	3-5 feet
Symphoricarpos vulgaris	Coral berry	3-5 feet
Rhus copallina	Black sumach	5-8 feet
Eleagnus angustifolia	Russian olive	10-15 feet
Opulaster opulifolius	Nine bark	4-7 feet

Hardy Vines

Vitis riparia	Wild grape	Arbors
Clematis Jackmanii		Trellises
Lonicera Japonica Halleana	Hall's Honeysuckle	Arbors and Trellises
Ampelopsis Tricuspidata Veitchii	Boston or Japanese Ivy	Brick or stone walls
Ampelopsis Quinquefolia	Virginia Creeper	Trellises
Ampelopsis Quinquefolia Engelmanni	Engleman's Virginia Creeper	Brick or stone walls
Aristolochia durior (sipho)	Dutchman's pipe	Arbors

Hardy Perennials

Achillea	Yarrow
Alyssum saxatile compactum	Perennial alyssum
Althea	Hollyhock
Aquilegia	Columbine
Anchusa	
Asters—hardy	
Campanula	Canterbury bell
Centaurea	Corn flower
Delphinum	Larkspur
Dianthus barbatus	Sweet William
Dicentra	Bleeding heart
Digitalis	Foxglove
Gaillardia	
Gypsophila	Baby's Breath
Iberis	Hardy Candytuft
Iris	
Myosotis	Hardy Forget-me-not
Papaver orientale	Oriental poppy
Paeonia chinensis	Peony
Phlox	
Pyrethrum	
Rudbeckia	Golden glow
Saxifraga	
Solidago Canadensis	Goldenrod.

Annual Bedding Plants

Low Growing for the Border

From Seed:	From Cuttings:
Sweet alyssum	Madam Salleroi geranium
Ageratum	Alternanthera
Candytuft	Achyranthus
Lobelia	Stevia
	Geranium

Medium to Tall Growing for Fillers

From Seed:	From Seed:
Aster	Ten weeks stock
California Poppy	Nasturtium
Marigold	Balsam
Petunia	Pinks
Phlox	Snapdragon
Verbena	Coreopsis
Zinnia	Feverfew
Salvia	Salpiglossis
Cosmos	Four o'clock
Sweet pea	

Bulbs

For Spring Planting:	For Fall Planting:
Gladioli	Tulip
Dahlia	Jonquil
Lilium Auratum	Narcissus poeticus
Tiger lily	Narcissus Von Sion
Red hot poker plant	Crocus
Canna	Iris
Caladum	Bleeding heart
	Peony
	Fritillaria



Plate No. 13.—THE BIRD BATH

It should always be located close in against a group of trees or shrubs. In this case the birds can be watched from the window.

PLANTING BULBS

Whether fall or spring-planted bulbs are being used, the soil requirements are much the same. It should consist of a rich, well-drained sandy loam, spaded deeply and put in first-class condition. The autumn-planted bulbs are best set about the time the leaves begin to fall. In setting any bulb, a safe rule is to set it so its top will be below the surface of the ground from three to five times its thickness. After the ground is frozen hard, it is advisable to mulch the bed with a light coat of stable bedding straw, leaves or other similar materials. This is removed when the ground thaws out in the spring. These bulbs may be left in the ground year after year, but the best results are obtained when they are taken up, divided and reset every three or four years.

The spring-planted bulbs are always taken up after frost kills them in the fall. They may be stored in a cool, dry cellar for the winter. The dahlia roots must be covered with slightly damp moss, dirt or other material to keep them from shriveling up.



Plate No. 14.—INTRODUCING THE POOL

Where there is room in the private area, a small lily or fish pool will add materially to the attractiveness of the composition.

CONCLUSION

In conclusion, the writer wishes to state that in dealing with all the problems involved in the correct beautifying of the small, residential tract we have a subject far too intricate and varied to handle properly in a treatise of so short a nature as this. There are many matters of detail not mentioned here that will naturally arise in the development of each individual landscape, and the suggestions given are only to be taken as a general guide.

Likewise in recommending a list of planting materials it must be understood that no attempt has been made to name all the different kinds that will grow in the different regions, but rather to suggest only those that are most likely to give satisfaction when tried in general over the State.

Lastly, make up your mind you are going to attempt to have a place that you and your family will be proud to call home; one that has an additional financial value far in excess of the amount you have spent in beautifying it, and one which the community can point to with pride. With this determination, undertake to do the job well and for an indefinite future and you will never live long enough to regret it.

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The Colorado Experiment Station
AGRICULTURAL DIVISION

THE EFFECTS OF NITRATES ON THE COMPOSITION OF THE POTATO

By WILLIAM P. HEADDEN

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The Colorado Agricultural College

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THE EFFECTS OF NITRATES ON THE COMPOSITION OF THE POTATO

By WILLIAM P. HEADDEN

A few years ago Colorado potato growers suffered heavy losses due to attacks of diseases. The difficulty appeared, according to C. L. Fitch, suddenly in 1911, continued during the years of 1911-'12-'13 and '14, and disappeared in 1915. The difficulty was spoken of in a general way as the Leaf Roll. My information is that several causes contributed to these unfortunate results.

The only part that the Chemical Section of the Station took in the investigation at that time was to visit the Greeley district and take a number of soil samples and determine the ratio of nitrate nitrogen to the total. This ranged up to 17 percent, whereas 5 percent is a high ratio under ordinary conditions, especially in soils occupied by growing crops.

We have nothing to do with the theories advanced to account for the trouble, but one of these attributed it directly to temperature and moisture of the soil. This is broad enough, and rich enough in indirect results, to cover a great many difficulties.

EXPLANATIONS OFFERED, NOT WHOLLY SATISFACTORY

The writer was convinced that a nearer approach to the cause would be made by studying the supply of plant food and the effect of the ratios of the different elements on the structure and composition of the plants. So far as I could learn, no new factor had been introduced into our conditions. The chief agents causing the trouble were considered to be *Alternaria*, *Fusarium* and *Rhizoctonia*, but these we have with us at all times, and it seemed to me then that there was some reason why these organisms should suddenly become so violently pathogenic, especially the *Fusarium*, to which I understood the greater part of the trouble was attributed. This violently pathogenic characteristic of the fungus was evidently acquired and persisted through those years. The organisms were present prior to this time and are with us still, but it was only for four years, in fact for a less time, that they were so harmful. It is the same organism all the time, capable under proper conditions of becoming very harmful. My idea was that one of the conditions was a condition of the plant, that, on the one hand offered less resistance, and on the other hand, furnished a bet-

ter medium for the development of the fungus than usual. If the cell walls were thinner or weaker than usual and the juices of the plant richer in nitrogenous compounds, such as asparagine for instance, the fungus might develop vigorously enough to occupy the whole stem of the plant with its mycelia.

The food elements on which we lay the greatest stress are phosphorus, potassium and nitrogen, the latter of which is almost wholly appropriated in the form of nitrates. An abundant, not to say excessive, supply of these promotes the vegetative processes, indicated, in most cases clearly, by the size and color of the leaves. In the case of wheat we have weak stems that knee and lodge badly and are clearly very susceptible to the attack of the rust fungus peculiar to the plant. I thought that a similar series of related facts might hold for the potato. If there be such, the conditions under which they become apparent are far less simple than in the case of the wheat plant. In the wheat plant we have three very pronounced effects shown by the application of nitrates; 1st, a darker leaf accompanied by weak straw; 2nd, a very pronounced susceptibility to rust; 3rd, a marked difference in the appearance and composition of the fruit. In the case of the sugar beet, we have an excessive foliage and a depression in the quality of the beet. I do not know whether any definite observations have been instituted to ascertain whether beets grown with an excessive supply of nitrates are more susceptible to the diseases that affect the plants or not. In all of the experiments that I made, we sprayed heavily in anticipation of such attacks.

EFFECTS OF NITRATES NOT SO PRONOUNCED ON GROWTH OF POTATOES AS ON WHEAT AND SUGAR BEETS

In the cultivation of potatoes at Greeley, Colorado, there was but little, if any, difference in the color and growth of the plants that received 800 pounds of sodic nitrate to the acre and of those that received none. There are two evident conclusions to be drawn; First, that the potato plant is not so sensitive to the supply of nitrates at its disposal as are the wheat and sugar beet plants; Second. that the natural supply in the soil is sufficient to produce an almost maximum effect on the growth of the vines. I am confident that both of these conclusions are partially applicable. One would be justified in asserting that there was no difference in the growth and color of the plants, but it certainly was not marked, as it always is in the case of wheat or of sugar beets. The growth of oats in the adjoining land, as well as data to be given subsequently, indicate an abundant supply of nitrates during the growing season. We demonstrated that the composition of the wheat plant and its fruit are both very materially affected by the relative supply of nitric nitrogen, and that these effects were

not produced by other forms of nitrogen, such as occur in farmyard manure nor by water; and for the sugar beet we demonstrated that an excess of nitrates produced very undesirable results. First, they affected the growth of the beet delaying maturation; they affected the quality of the beet increasing the injurious nitrogen and injurious ash and depressed the sugar content. The juices of these beets do not work well in the factory for several reasons; first, because they are the juices of green beets; second, because of the presence of injurious forms of nitrogen and of ash constituents which interfere with the crystallization of the sugar, or to express it otherwise, they are molassegenic factors. Again, the nitrates affected the shape of the beets causing them to grow sharply top-shaped, producing a high percentage of crown and a yield of topped beet disproportionate to that indicated by the growth of the tops. The development of the potato is entirely different from that of these crops, still the fundamental requirements of the plants are essentially the same so far as plant food is concerned, and we supposed that an undue supply of nitrogen would, in this case as in the others, produce definite characteristics in the composition and structure of the plant that would help in explaining the experiences had by potato-growers in the Greeley and other districts of Colorado in the years given, 1911 to 1914 inclusive.

TEMPERATURE, DRAINAGE AND SOIL-ATMOSPHERE

The factors of temperature and water supply cannot be left out of consideration. How important a part these factors may play in this question the writer does not know, nor has he found anything in the literature accessible to him that is, in any measure, satisfactory. That the potato produces well and that the produce is usually of good quality in mountainous sections might be taken to indicate that the temperature and drainage of these sections were determining factors in the case, and that the soil had less to do with it. This may be so, but the diseases that we have to complain of are present in our high valleys. San Luis Valley, with an altitude of 7,500 feet, has been as sorely afflicted as Greeley. In these cases the climates are very different. I do not know the maximum temperatures nor their duration at these places, but the San Luis Valley may have frost every month in the year. Their nights are cool. Their soil is, for the most part, well adapted to the culture of potatoes and yet there are portions of this valley in which, I am informed, the potato crop is more often a failure than a success; in other portions of the valley this crop is usually dependable and profitable, and it certainly would lead us into very great perplexities if we should attempt to discuss the relations of water to these problems.

The relation of temperature and moisture to the problems involved in the culture of the potato involve the biological

activities of the soil, and these in turn involve the character of the soil atmosphere. These factors are to me of unknown potentialities, but we must assume that they are factors of some importance and it is evident that temperature and moisture are of very great importance in this respect.

It is scarcely surprising that we have not ascertained the conditions which determine the outbreak of diseases, as in 1911 in the Greeley district, or those under which the disease or diseases persist in certain sections.

OBJECT STATED—RESULTS NOT CONCLUSIVE

The object had in view in undertaking the experiments recorded in this bulletin was to study the composition and characteristics of our potatoes, and more especially to find out what, and how great an influence an excessive supply of nitrates may have upon the growth, composition and health of the plant, i. e. whether it rendered it more susceptible and less resistant to disease than other plants. In the latter respect our results are, to say the very best of them, inconclusive. No one has suffered from disease during the period of our experiment as they did in 1911-'14, and our potatoes have been much like everybody else's. At the present writing it remains to be seen whether the keeping qualities of the tubers produced under the different conditions are equally good. The crop of 1920 did not show any difference that was noted, but the crop of 1921 gives indications of differences so marked that a satisfactory interpretation may be made to the effect that the tubers produced on the plots having received an application of 800 pounds of sodic nitrate per acre are inferior in this respect to those from plots that received no application of nitrates.

The pathological features of these experiments lie beyond my province and it is not my intention to go beyond the general statements already made. I shall confine myself to the study of the chemical composition of the soil, the plants and tubers produced. I have had nothing to do with the cultivation of the plots beyond advising the amounts of nitrates to be applied. The cultivation was, however, standard for the Greeley district and thorough, so that no degree of failure whatsoever is to be attributed to mistakes in cultural methods or to indifferent execution. The experiments were seriously interfered with in 1920 by a severe hail storm which beat down, cut and bruised the vines so badly that we made no study of them. But we did carry through the whole series of samples of tubers, except that we made no cooking experiments, which, for the purposes had in view in this work, is not of such direct importance as the composition and other properties of the tubers. We shall, however, in a subsequent bulletin, record this feature for the crop of 1921 because it has a popular interest, is a

recognized property of the tubers, and completes a little more fully our investigation of the subject. These cooking qualities give us another measure of the value for the potatoes.

CULTURAL METHODS NOT DISCUSSED

The cultural method prevalent in the Greeley district is that of "high hilling." This means that the plants stand in a ridge so high above the bottom of the irrigating furrow between the ridges that the irrigating water is applied below the point where the tubers are formed, and reaches them by capillary rise through the soil. In this way the tubers develop in a well-drained and well-aerated soil. These conditions should be borne in mind in connection with the soil samples taken during the growing season, as these were taken close to the plants, and from the middle of the top of these ridges. It will be recognized that in this work we are not concerned with the discussion of methods of cultivation; our potatoes were cultivated in this manner, and our soil samples represent these conditions. Discussion of the methods of cultivation is given in almost every bulletin published on the subject of potato growing.

THE SOIL

The soil is classified as Fort Collins loam. It is somewhat clayey and cannot be considered as a real good potato soil. The subsoil varies somewhat within the area used in these experiments. The soil, as this term is understood, is about twelve inches deep and is not very different from the subsoil, which, however, is a little heavier and occasionally contains segregations of carbonate of calcium; sometimes they are mixed with, or may be largely composed of sulfate of calcium.

We shall present in the following pages the mechanical, mass and agricultural analyses of samples of this soil. The agricultural analyses have been made using two methods of extraction, concentrated hydrochloric acid and fifth normal nitric acid. These analyses are given in order that those who wish to study the features involved in the total supply of plant food may have as complete a statement of the case as we can give from which they can make their own deductions. We cannot, unfortunately, present the biological characteristics of these soils except in so far as the fixation and nitrifying efficiency of these samples may be a measure of, perhaps, the most important of these biological features. We hold these to be of the utmost importance, not only in connection with the diseases which wrought such damage in the years of failure but at all times in the nutrition and growth of the plants. I believe them to be more worthy of study than the purely chemical factors to which, in the main, we must confine ourselves. That the relations between these factors are intimate is certainly beyond question. The difficulties in establishing what

these relations may be are probably great, but they will be established, and we shall someday know how intimate and important these relations are.

We shall take up no space with description of methods of investigation, as we have followed well-beaten paths. If, at any point, we have deviated, we shall make definite statements to this effect.

We have made mechanical and mass analyses of the soils only, as we see no gain in making these analyses of the subsoils.

MECHANICAL ANALYSES OF THE GREELEY SOILS

	Percent
Over 1 mm.	0.160
1 mm. to 0.5 mm.	1.431
0.5 to 0.25 mm.	1.723
0.25 to 0.05 mm.	54.752
0.05 to 0.01	20.057
0.01 to dust	15.206
Fire clay	2.530
Ignition	4.141
	100.000

MASS ANALYSES OF THE GREELEY SOILS

Laboratory number	2618	2622	2624	2630	2632
	Percent	Percent	Percent	Percent	Percent
Moisture at 115°	2.189	2.050	1.753	1.800	1.762
Ignition	3.075	4.070	3.195	2.880	3.200
SiO_2	77.100	75.580	76.210	77.540	77.080
TiO_2	0.481	0.480	0.496	0.290	0.505
SO_3	tr	tr	0.135	0.170	0.024
CO_2	tr	tr	tr	none	tr
Cl	0.087	tr	tr	tr	tr
P_2O_5	0.124	0.080	0.135	0.110	0.125
Al_2O_5	8.759	8.650	0.925	8.420	8.059
Fe_2O_3	3.304	3.610	3.200	3.360	3.260
Me_3O_4	0.150	0.220	0.047	0.110	0.045
CaO	1.180	1.500	1.250	0.960	1.400
MgO	0.724	1.040	1.086	0.860	0.968
K_2O	2.184	2.040	2.622	2.440	2.572
Na_2O	1.004	1.040	1.305	1.220	1.049
CuO	tr	....	....	....	....
As_2O_3	tr	....	....	....	....
Li_2O	None				
Sum	100.361	100.36	100.459	100.160	100.045
O = Cl	0.021				
	100.340	100.36	100.459	100.160	100.045
Total nitrogen.	0.0832	0.0950	0.0891	0.0790	0.0850

The excess in the following analyses, an excess of nearly two percent, is much too great, but the determination made on the solutions were repeated in many instances and no considerable errors were found, and I do not think the excesses in the summation of sufficient importance to justify a repetition of the whole analysis, so I give the analyses as obtained. The soluble silicic acid in the statement of an agricultural analysis of a soil may be of importance as being a measure of the silicates present in the soil capable of entering readily into the reactions that may be going on in it. But in any attempt to discuss these reactions of which we are still in doubt, it can make but little difference whether the soluble silicic acid be given as 14.9 or 15.4, which is approximately the difference

that would fall upon the soluble solicic acid if the excess were distributed. I have preferred to state the results just as the analyst reported and I accepted them.

AGRICULTURAL ANALYSES OF GREELEY SOILS*

Laboratory number	2618	2620	2622	2624	2630	2632
	Percent	Percent	Percent	Percent	Percent	Percent
Moisture at 115°	1.650	2.226	2.974	2.179	2.118	2.175
Ignition	3.056	3.789	3.829	3.360	3.357	3.012
Insoluble	72.646	71.394	69.651	75.080	76.553	78.425
Soluble Si O_2	14.814	13.092	13.566	11.862	10.908	9.346
SO_3	0.072	0.051	0.054	0.062	0.031	0.034
CO_2	0.200	0.425	0.564	0.100	0.058	0.196
Cl	0.262	0.796	0.188	0.077	0.275	0.289
P_2O_5	0.096	0.127	0.061	0.096	0.061	0.057
Al_2O_3	0.334	3.543	4.505	3.474	2.504	3.168
Fe_2O_3	3.930	3.440	2.910	2.680	2.765	2.650
Mn_3O_4	0.520	0.250	0.240	0.230	0.215	0.380
CaO	0.660	1.075	1.295	0.690	0.545	0.610
MgO	0.876	0.902	1.035	0.734	0.650	0.463
K_2O	0.771	0.639	0.466	0.645	0.510	0.421
Na_2O	0.386	0.214	0.326	0.542	0.230	0.166
Sum	100.273	101.963	101.674	101.811	100.780	101.392
O equivalent to Cl	0.059	0.180	0.042	0.017	0.062	0.065
Total	100.214	101.783	101.632	101.794	100.718	101.327

*Digestion with HCl sp.g.1.181 or concentrated acid for 10 hours (nominally).

AGRICULTURAL ANALYSES OF THE GREELEY SUBSOILS*

Laboratory number	2619	2621	2623	2625	2631	2633
	Percent	Percent	Percent	Percent	Percent	Percent
Moisture at 115°	1.966	3.600	3.340	3.110	3.621	1.873
Ignition	2.983	3.624	3.817	3.287	4.008	2.943
Insoluble	66.793	65.419	66.641	70.766	65.764	73.003
Soluble Si O_2	17.503	14.998	14.890	13.819	14.913	11.879
SO_3	0.041	0.078	0.075	0.045	0.031	0.017
CO_2	0.150	1.239	0.057	0.040	0.000	0.100
Cl	0.247	0.265	0.213	0.186	0.215	0.76
P_2O_5	0.153	0.143	0.098	0.127	0.071	0.074
Al_2O_3	2.477	2.164	5.300	4.830	5.649	3.826
Fe_2O_3	4.550	3.563	4.105	3.030	3.380	3.480
Mn_2O_4	0.630	0.240	0.280	0.240	0.300	0.430
CaO	0.650	2.270	0.643	0.555	0.505	0.500
MgO	1.083	1.107	1.065	0.845	0.947	0.880
K_2O	0.587	0.628	0.876	0.535	0.735	0.556
Na_2O	0.440	0.401	0.214	0.534	0.507	0.376
Sum	100.253	101.749	101.714	101.949	100.646	100.113
O equivalent to Cl	0.056	0.060	0.048	0.042	0.049	0.040
Total	100.197	101.689	101.666	101.907	100.597	100.073

*Solvent concentrated hydrochloric acid.

These subsoils were taken from the 13th to the 24th inch, both inclusive and represent the second foot of this land. There are differences in composition, but so far as one would venture to judge from these analyses, these subsoils are quite as good as the soils when properly aerated. The differences in the amounts of organic matter must be approximately the

same as the differences in the loss on ignition, which are very small. The total ignition is low, showing that in these soils the sum of organic matter and water retained at 115 degrees amounts to rather less than four percent. In only one instance does the sum of these two amount to this much. This is rather surprising, as this land had been in alfalfa which was broken up only a little while before these samples were taken.

EFFECTS OF ALFALFA NOT APPARENT

The whole soil was taken but the larger alfalfa roots, of course, were rejected. We would expect the surface foot to be enriched in organic matter to a greater extent than we find it. The amount of leaves and small stems lost in making alfalfa hay is very considerable, amounting to about 20 percent of the total dry matter produced by the crop of alfalfa. By this is meant that if 4 tons of hay were actually gathered from an acre of this land in 1919, there had been produced 5 tons of dry matter, one ton of which had been left in the land and was equivalent to the application of 70 pounds of nitrogen and 170 pounds of ash constituents. The rotation followed in this case calls for two years in alfalfa. The land had received approximately twice these quantities, together with the plants themselves, but the differences shown by the analyses give no hint of these facts. One would, it is true, scarcely expect to find results due to the direct additions made, because they are too small when figured in percentages, but we would be justified in this case in expecting a gross accumulation of organic matter at least pronounced enough to be detected. These analyses do not show any such desirable effects of the alfalfa. We shall, however, have further opportunity to learn of conditions in these soils; in the meantime, it is not to be inferred that we doubt the benefits of the rotation, but we are a little surprised that the beneficial effects do not appear to be reflected in appreciable measure in the analytical results. The digestion with concentrated hydrochloric acid is, beyond doubt, rather drastic if we expect to draw conclusions from the results regarding the actual amounts of food supply available to the plants at the time the samples were taken. The method, however, certainly gives us maximum limits for these amounts, and in a measure gives us the immediately potential resources of the soil. In this view and in this view only, we have considered it advisable to present such analyses of the soil. For the purpose of obtaining a better view of the more immediately available resources of this soil, we avail ourselves of the fifth normal nitric acid extract.

The analyses of the subsoils are given in the same order as those of the soils, so that the analysis of the subsoil falls under the corresponding soil to which it belongs; laboratory number 2619 falls under 2618 with which it pairs. Of course intervening text is neglected.

As the moisture, ignition, carbon dioxid and chlorin determinations were made on the general samples, they are common to the two sets of analyses.

AGRICULTURAL ANALYSES OF GREELEY SOILS*

Laboratory number	2618	2620	2622	2624	2630	2632
	Percent	Percent	Percent	Percent	Percent	Percent
Moisture at 115°	1.650	2.226	2.974	2.179	2.118	2.175
Ignition	3.065	3.789	3.839	3.360	3.357	3.012
Insoluble	92.200	90.790	89.930	91.459	92.110	91.910
Soluble SiO_2	1.700	1.610	1.660	2.101	1.980	2.140
SO_3	0.010	0.010	0.010	0.017	0.017	0.027
CO_2	0.200	0.425	0.564	0.100	0.058	0.196
Cl	0.262	0.796	0.188	0.077	0.275	0.289
P_2O_5	0.058	0.077	0.058	0.058	0.077	0.070
Al_2O_3	0.289	0.038	0.176	0.334	0.239	0.263
Fe_2O_3	0.210	0.330	0.290	0.270	0.290	0.290
Mn_2O_4	0.230	0.300	0.210	0.260	0.230	0.280
CaO	0.500	0.920	1.040	0.560	0.420	0.500
MgO	0.195	0.261	0.279	0.253	0.232	0.232
K_2O	0.200	0.161	0.211	0.137	0.112	0.118
Na_2O	0.010	0.021	0.016	0.075	0.042	0.053
Sum	100.770	101.528	101.445	101.030	100.834	101.492
O equivalent to Cl	0.059	0.197	0.043	0.018	0.062	0.065
Total	100.711	101.331	101.402	101.012	100.772	101.427

*Extraction with n/5 nitric acid.

AGRICULTURAL ANALYSES OF GREELEY SUBSOILS**

Laboratory number	2619	2621	2623	2625	2631	2633
	Percent	Percent	Percent	Percent	Percent	Percent
Moisture	1.966	3.600	3.440	3.110	3.621	1.873
Ignition	2.983	3.634	3.817	3.287	4.008	2.943
Insoluble	91.470	87.820	90.550	91.779	89.197	91.990
Soluble SiO_2	1.490	1.530	1.490	1.611	1.480	1.620
CO_2	0.150	1.239	0.057	0.040	0.000	0.100
Cl	0.247	0.265	0.213	0.186	0.215	0.176
P_2O_5	0.064	0.083	0.051	0.051	0.064	0.083
Al_2O_3	0.100	0.272	0.138	0.251	0.175	0.313
Fe_2O_3	0.310	0.330	0.310	0.260	0.440	0.270
Mn_2O_4	0.260	0.270	0.250	0.250	0.220	0.220
CaO	0.500	1.980	0.510	0.440	0.420	0.400
MgO	0.232	0.377	0.275	0.235	0.250	0.256
K_2O	0.244	0.165	0.215	0.103	0.124	0.114
Na_2O	0.026	0.037	0.042	0.047	0.064	0.064
Sum	100.059	100.615	101.320	101.670	100.208	100.439
O equivalent to Cl	0.055	0.059	0.048	0.042	0.048	0.039
Total	100.004	100.556	101.272	101.628	100.160	100.400

**Extraction with n/5 nitric acid.

SUPPLY OF POTASH AND PHOSPHORIC ACID ABUNDANT

Personally I am not convinced that an attempt to interpret the results of these analyses will serve any good purpose. The big features are so plain that anyone interested enough to read them can see that even with the weaker solvent, fifth

normal nitric acid, an abundance of phosphoric acid and potash goes into solution to meet the requirements of many more crops than this, and several generations can grow on these lands. The amount more or less readily available, i. e. soluble in fifth normal nitric acid would suffice to grow 115 crops of 200 bushels of potatoes to the acre, and the amount soluble in hydrochloric acid would meet the requirements of the 200 bushel crop of potatoes for 170 years more, and beyond this lies a much larger supply especially of potash. These statements assume that the surface soil to the depth of one foot alone supplies the phosphoric acid and potash requirements of the potato crop which is by no means the case, for the roots of the potato plant penetrate freely to a depth of two feet and often to a depth of four feet. The extraction of the soil by concentrated hydrochloric acid probably gives very nearly the whole of the phosphoric acid present in the soil but by no means the whole of its reserve in potash, as the felspars are only very slowly attacked by this agent and even the phosphoric acid extraction is not complete.

The soluble silicic acid, which is abundantly present, probably should be interpreted as showing a relatively large amount of easily decomposed silicates consisting of silicates of alumina with lime, potash and soda and also containing water. Such silicates are very reactive and our soils ought to respond quickly and favorably to the application of such fertilizers as may be needed. The fact that the application of commercial fertilizers has heretofore failed to give the hoped for results is accounted for by the considerations presented in this connection.

NO ATTEMPT MADE TO ACCOUNT FOR SMALL YIELD

It might be thought that I should go further in this direction and attempt to explain why the yields obtained in this district are not two or three times as large as they are. This I cannot do. Perhaps they should be two or three times as large as they are. The plant food is in the soil in abundance, but there are other factors operative in the case that limit the crops to their present volume and influence the quality as well. I have already stated, rather plainly I think, that the object had in view in undertaking this work was not to study cultural methods or results but to study a single feature, almost exclusively, as possibly the determining cause for the failures of the past. The work done in the prosecution of this study has had this one object in view. Much fundamental work has been done because the desired facts had not previously been acquired and put on record. We had no intention of going into a study of the ratios existing between the quantities of plant food supplied by the soils, nor of experimenting to solve such problems. So far as I know this presents a class of problems never undertaken for our soils; I know that experiments

have been made with artificial fertilizers, but the results have been disappointing. It may be that the preceding paragraphs offer the explanation and perhaps they do not. My personal conviction is that the suggestions relative to the supply of phosphoric acid and potash, the inorganic elements universally considered of primary importance, are not satisfactory and adequate to the explanation of the facts.

WATER-SOLUBLE PORTION OF OUR SOIL NOT VERY IMPORTANT

The water-soluble portion of our soils is usually large, much larger than that of eastern and European soils in which this plant is grown. I do not know whether this is a factor in our questions or not. I presume that it is, but what part it plays I do not know. Abundant yields are obtained in lands heavily impregnated with our ordinary alkalies and also in lands free from them from which it would follow that sodium, calcium and magnesium salts are not important factors in the problems presented. These are, so far as my knowledge goes, unexamined phases of the problem. These may be important phases but our observations in different parts of the state do not lead us to consider them as promising subjects for investigation. If my impressions in this matter be entirely at fault, it still remains very clear that the chief difficulties in potato-growing complained of are not involved in these features, for these are all constant factors; I may say, universal and permanent factors in our questions, whereas the difficulties mostly complained of are variable in the extreme. I have already cited a case in which the same land produces a good crop once in four or five years and failures the other three or four years. The plant foods and their ratios are probably just as abundant and favorable, and the alkalies no more abundant during the three or four unfavorable years than during the good one.

NO GENERAL SOLUTION OF THE PROBLEM PROBABLE

These things unite in showing that the problems are complex to such an extent that a solution of them all at one time or the finding of one general cause is not at all probable. The best that one is justified in hoping for is a series of partial solutions which may at times not be in harmony with one another and need much adjustment to one another to make them seem at all reasonable. The problem presented in this bulletin is: What are the effects of nitrates in the soil upon the growth, composition and properties of the potato plant and tubers? Under properties in connection with this problem, we consider the susceptibility to disease more important than the usually considered cooking qualities, though these, too, will be included later. We assume that the spores of the various fungi to which our destructive diseases are due are sufficiently

abundant to infect a sufficient number of potatoes, especially if bruised, to demonstrate the susceptibility of the crop as shown by the keeping quality of the tubers. If there are twice as many tubers, grown with nitrates, that show infection with fungi as there are affected tubers of the same variety grown in the same plot of land but without the application of nitrates, we conclude that the nitrate added has increased the susceptibility of the tubers to the attacks of these fungi, be they what they may.

POTATOES CONSIDERED IN THIS BULLETIN

In the succeeding pages of this bulletin we shall address ourselves to the composition and qualities of Colorado-grown tubers in general,—the composition and qualities of tubers grown in the Greeley district with and without the application of nitrates, and the composition of the vines grown with and without nitrates. The pathological features lie beyond our province except in the most general way.

No study of the potatoes peculiar to the Greeley district has been made. Only potatoes grown on our own experimental plots have been examined or will be discussed. In this statement "our own experimental plots" means on the plots of the Colorado Potato Experiment Station. It may be well in this connection to state that Dr. H. G. MacMillan of the Bureau of Plant Industry, U. S. Department of Agriculture, pathologist at the Potato Experiment Station, with whom it has been a pleasure to be associated in this work, is in no measure whatsoever responsible for the statements made in this bulletin. Any errors contained herein are mine and not his. At the same time I am glad to acknowledge my obligations to him for willingly given information, advice and words of encouragement. He has, however, no responsibility for either the statements of facts or the conclusions set forth in this bulletin.

NITROGEN IN THIS SOIL

In the statements of the analyses of the soils heretofore made, the question of nitrogen has not been mentioned, because I propose to address myself to this subject almost to the exclusion of the other factors. The total nitrogen shown in the analyses is below the average for good soils. One reason for laying stress upon the nitrogen content of the soil is evident from the statement of the purpose that we had in view. We surmised that these soils furnished enough nitrogen during the growing season to constitute an excessive supply for the potato plant and render it less resistant than normal to the attack of disease, and that in the years of severe attacks the amount furnished had been sufficient to be very deleterious when occurring in conjunction with other conditions tending to produce the same results. In other words, the effects of the nitrates upon the growth of the plant render the cell walls

weaker and the juices richer in nitrogen, making the latter a better medium for the sustenance of the fungi, and the cells less able to resist their attacks. With these considerations in view, we attempted to follow the development of the nitrates in the soil during the season.

This land had been in alfalfa for two years and the stubble with a growth of at least four inches had been plowed under only a short time previous to the taking of the samples. We had in the surface foot of soil the accumulated effect of the two years in alfalfa with that of the crop plowed under. The roots were still green and were not taken with the sample. The samples were air-dried which, according to determinations made, means from 1.9 to 3.0 percent of moisture in the soil.

INCUBATION TESTS

The first question that we tried to establish in regard to the relation between this soil and nitrogen content was its ability to fix and nitrify nitrogen. The original content of total nitrogen and nitrate nitrogen is given in the following table.

The moisture content of the soil was made up to 15-17 percent with ammonia-free water and incubated for periods of 30 and 40 days, when the nitrogen determinations were repeated. No source of energy was added to these. The experiments imitated field conditions as nearly as possible in a small way.

The supply of energy that the soil flora found in the dishes would have been available to it in the field. It may be stated, however, that all of the soils that we have tested develop a luxuriant growth of algae; of course this growth is mixed. The following incubation tests were made with the samples whose analyses have been given, and were made immediately after the samples were taken 20 March, 1920:

INCUBATION EXPERIMENTS WITH THE SOILS

LABORATORY NO.	At the Beginning		After 30 Days		After 40 Days	
	Total Nitrogen	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen
2618, surface 12-in....	0.0832	0.00116	0.08687	0.00321	0.0851	0.00400
2619, subsoil 12-in....	0.0668	0.00111	0.07050	0.00315	0.0720	0.00270
2620, surface 12-in....	0.0863	0.00258	0.09125	0.00292	0.0900	0.00360
2621, subsoil 12-in....	0.0801	0.00160	0.08700	0.00222	0.0813	0.00275
2622, surface 12-in....	0.0950	0.00198	0.10720	0.00263	0.1003	0.00302
2623, subsoil 12-in....	0.0650	0.00116	0.07666	0.00321	0.0771	0.00295
2624, surface 12-in....	0.0891	0.00140	0.09350	0.00303	0.0935	0.00395
2625, subsoil 12-in....	0.0689	0.00140	0.08900	0.00268	0.0721	0.00302
2630, surface 12-in....	0.0790	0.00163			0.0905	0.00412
2631, subsoil 12-in....	0.0632	0.00140			0.0715	0.00327
2632, surface 13-in....	0.0850	0.00081			0.0862	0.00387
2633, subsoil 12-in....	0.0567	0.00215			0.0645	0.00275

As the result of the changes going on in these samples, we find at the end of 40 days an increase in the total nitrogen ranging from 12 to rather more than 100 p. p. m., or from 75 to 625 pounds of proteid matter per million of soil. This in-

crease in total nitrogen is shown by the subsoils as well as by the soils. One of the subsoils gives an increase, calculated as proteid matter, of 750 pounds per million. This sample was taken 12 inches deep, i. e. a layer of subsoil 12 inches thick and approximately 12 inches square was taken out, mixed on a canvas and sampled, so that the results obtained show the fixing power of that subsoil taken one foot deep. Under the conditions of our incubation chamber, which differed from those in the soil probably in aeration and moisture and certainly in temperature, an acre-foot of this subsoil is capable of producing 2600 pounds of proteid matter in 40 days. Such facts remove the assertion that this soil and subsoil possess a fixing power for the atmospheric nitrogen from a general statement and establish it as a definite fact and give us a fair measure of its amount which varies, but is of sufficient magnitude to leave no doubt about its actuality as a factor.

The amount of nitric nitrogen ordinarily present in good soils, not occupied by growing crops, is about 8 p. p. m. We observe that while the total nitrogen in this soil is scarcely up to the average quantity present in good soils, which may be taken at one-tenth of one percent, which is generally considered the lowest adequate limit for the nitrogen supply, the nitric nitrogen is materially above the maximum usually present, even as much as three times this amount. It is to be remembered that these samples were taken 12 and 15 inches deep and represent the soil and subsoil and not the surface inch or two of the soil in which much larger amounts of nitric nitrogen may be found. No such surface samples of this soil have been examined. These samples representing the plots on which we grew our potatoes were more than ordinarily rich in nitric nitrogen to begin with, which would justify the inference that their nitrifying power was more than an average one; the incubation tests show that every sample, whether of soil or subsoil, made an increase varying from one and a half time to over four times the amount present at the beginning. The prevailing gain was between two and three times the amount originally present. These properties are not mentioned as peculiar to Greeley soils, for we know them to be common to most of our soils, but they are present in a large measure in these soils on which we made our experiments.

Some of the plots that we planted to potatoes abutted upon land planted to oats which at this time, 20 May, indicated by the color and size of the leaves that their supply of nitrogen was abundant. We took four samples from this oat plot for the determination of the nitric nitrogen. We found in the samples taken to a depth of 3 inches, 19.9 and 13.4 p.p.m. of nitric nitrogen, and in those taken from 4 to 6 inches we found 18.6 and 13.2 p. p. m. The oats grew rankly and lodged. They had at this date the equivalent of 223 pounds of sodic nitrate available in the top 6 inches of the soil. The first sample in

each pair was taken from the north end, and the second from the south end of the field which was probably 1000 feet long.

NITRATES FORMED IN THE SOIL

Since the potatoes were cultivated by the "high hilling" method, the ridge in which the potato vines stand receives no water directly from the irrigating ditch, but is moistened from the sides by capillarity. The surface is not puddled or baked but is mellow to a depth of several inches. This condition allows of excellent aeration and together with the moisture is favorable to both the increase of the total nitrogen by fixation and to its nitrification. On the other hand, the occupancy of the ground by the rootlets of the plant may tend to inhibit both of these processes. The presence and growth of the plant on the one hand tends to inhibit, and on the other to use up the nitric nitrogen or nitrates formed. The nitric nitrogen found in soils occupied by growing plants is what is left of that which is formed under adverse conditions. We appreciated these relations and assumed both series of facts to be operative, still we took samples of this soil from the center of these ridges and close to the plants; in taking the later samples it was quite common to cut into a tuber. The samples were taken with a soil tube to a depth of 3 to 4 inches. 20 subsamples were united to form a composite sample, a plug was taken every 15 feet alternately from the two central rows of the plot. Six series of samples were taken during the season. We should have had a fallow plot treated in the same manner as the planted area but we did not foresee the advisability of this at the beginning. We later attempted to correct this omission but the plot was not satisfactory as the conditions were not comparable.

It is understood that no samples were taken from land to which we had applied nitrates, only from the check plots. There were four rows in each check plot and we took our samples from the two middle rows only, using the two outside rows as guard rows.

NITRIC NITROGEN IN P.P.M. IN THE HIGH CROWNED ROWS OF POTATOES

Plot Number	7 July	26 July	6 Aug.	9 Aug.	2 Sept.	16 Sept.
1 west	27.3	65.0	69.2	70.2	187.0	33.0
2 west	27.8	49.5	68.0	85.5	34.0	38.0
3 west	26.5	42.1	66.0	52.3	40.0	39.0
4 west	24.3	40.6	65.0	80.7	47.8	39.5
5 west	21.0	47.0	82.0	79.5	46.0	41.0
6 west	25.7	46.7	60.7	79.5	63.5	30.6
7 west	28.2	74.0	51.3	50.8	60.6	28.8
8 west	26.8	70.2	37.8	47.5	42.8	25.5
9 west	27.3	45.2	60.2	53.0	49.0	38.8
1 east	20.2	59.7	72.0	54.0	54.5	40.8
2 east	21.0	43.4	48.0	56.5	36.8	46.5
3 east	22.0	53.5	91.0	59.0	42.5	37.5
4 east	20.5	58.7	56.0	49.0	39.0	25.2
5 east	21.3	66.0	56.7	33.0	12.3	13.3
6 east	22.0	59.2	40.5	54.0	29.7	16.8

The samples of this soil taken in May are not comparable in any way to these for they were taken to a depth of one foot shortly after having been plowed to a depth of 9 inches, whereas these samples were taken to a depth of 3 to 4 inches only, after six weeks or thereabouts of alternate rest and cultivation. I cannot state whether it had been irrigated in the meantime or not, but I think not. We see that the nitric nitrogen is already high in early July and increases until 9 August, but then falls almost to the level of early July except that the southern part of our samples, 1, 2, 3, 4 and 5, west plot, fell slowly after September 1.

Moisture determinations were not made in these samples at the time of taking, but they probably contained from 13 to 15 percent including the dry surface soil that was taken with the sample. At times the samples taken may have carried more than 15 percent moisture, but the average was not far from this figure.

SOIL CONDITIONS UNDER WHICH OUR EXPERIMENTS WERE MADE

The conditions of the soil, so far as the questions under consideration are involved, were, at the beginning of our experiments as follows: mechanically, it was rather heavy for our purposes, it is in the lower part of the field, but is only fairly well drained. An alfalfa sod had just been broken up, our water supply was sufficient for irrigating it; the supply of potash and phosphoric acid soluble in fifth normal nitric acid was adequate for the production of many crops; the total nitrogen in the soil is low; the surface soil, taken to a depth of 12 inches, of our west plot averaged 0.0884 percent and that of east plot taken to about the same depth averaged 0.0820 percent. The subsoil in the west plot, taken 12 inches deep, average 0.0704 and in the east plot 0.06 percent. The humus was not determined, but it is evidently present in very moderate quantities even in the very surface portions of the soil.

These percentages of nitrogen found in the soil at the beginning of our experiments are from one-tenth to one-fifth below the generally assumed adequate lower limit of nitrogen for the production of good crops. The nitric nitrogen present in the top foot of this soil is from one and a half to three times as great as the maximum usually found in good soils, while the subsoils have nearly the same average. The nitric nitrogen in the surface soil on 20 May was 11.0 percent of the total, whereas about 5.0 percent is usually the maximum ratio found under ordinary conditions.

SOIL SHOWS STRONG FIXING POWER

As the results of incubation tests we find that the surface soils fix from 37 to 121 p.p.m. of nitrogen in 30 days and the

subsoils from 37 to 121 and even 201 p.p.m. of nitrogen. At the end of 40 days the maximum fixation is 121 p.p.m. and the minimum is 12 p.p.m. In no case during either the 30 or 40-day period did a reverse process set in with sufficient intensity to offset the fixation, so that at the end of 40 days every sample contained more nitrogen present than at the beginning. The nitrification that took place was apparently more rapid during the last ten days of the incubating period than during the first 30 days. There were some cases in which the gain was small, but none showed a loss. When we study the nitrification as it took place in the soil in the field, we find that it proceeds in a more marked degree than in our incubator. The samples of soil taken on 20 May contained from 11 to 25 p.p.m. of nitric nitrogen. On 7 July, samples taken four inches deep ranged from 20 to 27 p.p.m.; by August 9 it had risen to the maximum for the season, ranging from 73 to 85.5 p.p.m. There were 15 composite samples in every set and 20 subsamples in each composite sample. On 2 September we found that the nitric nitrogen had fallen to a range of from 12 to 63 p.p.m. except in one instance in which it reached the individual maximum for the season, 187 p.p.m. From 2 to 16 September, there was a further decrease, and the range was from 13 to 46. No general sets of samples were taken after this date. All of these field samples were taken from the middle of the crest and near the plants in the rows. Vacant spaces and the slopes of the ridges were carefully avoided because our experience has taught us that vacant spaces in the rows, i. e. (fallow) spots in such cultivated ground and the area just a little way above the water line in an irrigating furrow, are places where nitric nitrogen may be very abundant compared with the rest of the soil.

It was not feasible for us to take samples more frequently than we did and we appreciate the fact that the six series of samples represent only the general course of development during the season, and is not a record of the changes that undoubtedly took place in the soil. Our figures represent only the gross results of all of the changes that had taken place in the soil during the interval between the taking of the samples measured by the amount of nitric nitrogen found on the given dates. We have not been able to consider in any manner the flora that brought about these changes. Our results are only the gross results, giving, as said above, simply the general course of the changes going on in the soil, measured by the nitric nitrogen present on certain dates. If the samples had been taken on other dates we would undoubtedly have gotten other results.

Another measure might have been adopted, in fact, we have adopted another measure for the total biological activi-

tics in the soil; i. e. the amount of carbon dioxide present in the soil atmosphere, but we have a great deal to do in this direction. The nitric nitrogen has been up to this point a better measure for our specific purpose perhaps than the carbon dioxide would have been, for the nitric nitrogen is the actual source of the nitrogen appropriated by the plant. It does not follow that the carbon dioxide in the soil is of no importance to the vigor and productiveness of the plant, either directly or indirectly, in a variety of ways. The task that we have set ourselves is specifically to determine, if possible, the effects of a large nitrogen supply upon the composition and properties of the potato plant and its tubers.

Under properties we consider, in this case, primarily their susceptibility to disease and this in a very general sense. It is evident why we have addressed ourselves to the questions pertaining to the soil used in which to grow the potatoes, and we think that we have given the soil conditions as fully as is required by our problem, to wit: its composition and its nitrogen fixing and nitrifying capacity, together with the actual amounts of nitric nitrogen available to the plant on our check plots, of which there were 15 in all, at six given dates during the season. At no time was there less than the equivalent of 72 pounds of sodic nitrate per acre in the top four inches of soil, and so small an amount was exceptional. In July this amount was between 250 and 400 pounds, and in August from 300 to 500 pounds, and in September from 250 to 150 pounds, with a strong downward tendency. In a single case of a composite sample we had the equivalent of 1122 pounds of sodic nitrate.

It may be well in this connection to give the amounts of sodic nitrate applied to the different plots in the hope of producing such extreme effects that we might be able to definitely ascribe them to the nitrate added. We applied it at the rate of 200, 400, 600 and 800 pounds per acre. These applications were made immediately after the potatoes were planted and were in addition to whatever may have been formed in the plots during the season. We have, I believe, a very good estimate of the amounts formed, provided that the nitrate added had no effect upon this factor, which, however, is not probable.

So far as the cultivation and irrigation are concerned, the standard practice of the district was followed in detail, so the results obtained have general application to this type of soil.

Mention has already been made of the fact that the 1920 series of experiments was rendered somewhat unsatisfactory by a hailstorm that visited the plots in August and did severe injury to the vines and that, on this account, we did no analytical work on this portion of the crop, but we analyzed

the tubers. While I do not know what the effect of such injury to the vines may have had on the compositon of the tubers, I take it for granted that it had some effect and probably a great deal; nevertheless, we analyzed the crop in preference to wholly rejecting the season's work, especially as the changes in the composition of the tubers is assumed rather than known.

ANALYSES OF TUBERS GROWN IN 1920

VARIETY—	Water	Dry* Substance	Ash	Fat	Protein	Crude Fibre	Nitrogen Free Extract	Starch Found
Early Ohio, check	79.18	20.82	1.03	0.09	2.65	0.55	16.50	14.83
Early Ohio, 800-lb. $NaNo_3$	79.68	20.32	1.10	0.12	2.69	0.42	15.90	15.20
Bliss' Triumph, check	81.30	18.70	1.08	0.11	2.68	0.51	13.32	12.88
Bliss' Triumph, 800-lb. $NaNo_3$	81.07	18.93	1.02	0.08	2.77	0.47	14.59	13.75
Rural, check	79.95	20.05	0.94	0.11	2.31	0.51	16.18	16.13
Rural, 800-lb.-$NaNo_3$	80.60	19.40	0.98	0.11	2.71	0.54	15.06	14.49
Downing, check	81.00	19.00	1.03	0.08	2.65	0.52	14.72	14.18
Downing, 800-lb. $NaNo_3$	78.36	21.64	1.00	0.07	2.75	0.49	17.32	15.26
Pearl, Check	79.50	20.50	1.05	0.08	2.44	0.54	15.94	14.54
Pearl, 800-lb. $NaNo_3$	79.20	20.80	1.02	0.07	2.58	0.56	16.56	14.25
Average	79.98	20.02	1.03	0.09	2.62	0.51	15.61	
Average Jordan and Winton	78.89	21.71	0.95	0.10	2.14	0.56	17.36	

*Dry substance was determined at 100 degress with no more than 75 mm. pressure, practically in vacuo.

The average composition of potatoes in their fresh condition, as given by Jenkins and Winton in their "Compilation of Analyses of American Feeding Stuffs" marked "Average" in table is very nearly the same as the average for our ten samples representing five varieties including both early and late sorts. We find the widest divergence in the protein and nitrogen-free extract. The range in the amount of protein in the different samples is from 2.3 to 2.8. The lower of these figures is from a check plot and the higher from one that received sodic nitrate at the rate of 800 pounds per acre. This difference is smaller than we had hoped to find, but it is consistently in favor of the potatoes grown with nitrate throughout the series, and the average stands 2.54 to 2.70 for the series, against 2.14 average given by Jenkins and Winton.

The next point of divergence is found in the case of the nitrogen-free extract for which our average is 1.75 percent lower than the average given by these authors. Our series, however, shows a maximum difference of 4.0 percent or the ranges are from 13.32 to 17.32; theirs is, for raw potatoes, from 14.05 to 19.98 percent. There is again only a very slight difference between the checks and those grown with nitrates,

the average is slightly in favor of those grown with nitrates. The differences between the individual pairs, however, are not consistently in one direction. three of them are in favor of the potatoes grown with nitrates and two in favor of the check plots. The figures representing the nitrogen-free extract cover all of the errors of the analysis plus or minus, and the results agree as well as one could expect, but conclusions regarding the effects of the nitrates based upon these differences alone would be, in my opinion, unjustified.

HOW OUR CHECK PLOTS FAILED US

The question of how much importance one is to attach to any differences, large or small, shown by such analysis or what interpretation, if any, is to be made, is an open one, especially in the light of the facts exhibited by the six sets of samples taken from check plots during the season, 7 July to 16 September, according to which there was during a period of three or four weeks nitric-nitrogen equivalent to as much sodic nitrate as we applied to three out of four of the series, so that the assumption that our check plots were grown without the application of nitrates is true only in a very technical sense; i. e. we did not apply any nitrates but there was during this period the equivalent of from 350 to 500 pounds of sodic nitrate present in the top four inches of the soil, and the samples were carefully taken to avoid exaggeration of the amount present. We intended that the check plots should be grown without any application of nitrates or any undue amount of them. It is evident that we did not realize our expectations in this respect, and all of our potatoes were grown with an abundant supply of nitrates only some had more than others for we added sodic nitrate at the rate of 200, 400, 600 and 800 pounds to the acre, but an exceptional result in the case of one check plot gave results equivalent to 1122 pounds of sodic nitrate per million in the top four inches of the soil, which is greater than the largest amount that we applied. Under these conditions our checks failed us, so far as our purpose was concerned, and we, in the end, are compelled to compare potatoes grown with a big supply of nitrates with such as presumably had a greater supply of them and we are not comparing potatoes grown with and without any unusual supply of them. Under these conditions the potatoes should show the same characteristics and composition varying only in some small degree according as the sample happened to have enough or not quite enough to produce a maximum effect. We were endeavoring to find out, first, what this effect actually is and its maximum. It is evident that we cannot, in this way, satisfactorily establish either the character or the extent of these effects. If we insist upon clear and definite results attributable to the amounts of nitrate that we apply, we shall have to repeat the whole series of experiments

under different soil conditions. All of the results that we have gotten or may get by continuing our experiments on this soil will be simply ascertaining the differences in the degrees in which excessive, but unknown, quantities of nitrates have affected the composition and properties of the potatoes produced.

We shall give, at another time, analyses of potatoes from other sections of the State grown with and without irrigation. In this way we shall be able to present characteristics of various potatoes grown elsewhere with those of ours, grown at Greeley, but this will be far from satisfactory, for we cannot give any of the soil factors. We can only assume that they were favorable and that the soils do not show either the fixing or nitrifying power of our Greeley soil. Still, we shall give analyses of such samples depending upon the characteristics of the locality as sufficient guides in the different cases. We cannot, of course, do this for the crop of 1920.

There remain only two points in the analysis of these potatoes to examine further,—the ash, and the forms in which the nitrogen may be present. We shall take up the latter next. From the ordinary analyses, to which I have added the starch determinations, it is evident that no error is made when we consider the nitrogen-free extract as consisting wholly of starch.

FORMS OF NITROGEN PRESENT

In independent investigations, made with the purpose of detecting sugars, dextrine, etc., we have failed to find these constituents which are sometimes given, but not, so far as I know, in fresh potatoes. The agreement between the determinations of the so-called nitrogen-free extract and starch, when one considers the manner in which the former is arrived at, and the difficulties of the latter determination, is very good indeed and leaves no reasonable ground for doubting their essential identity. The only differences in these analyses, as stated in the table which can be attributed to the nitrate applied, is in the amount of protein present. We have endeavored to ascertain whether there are any differences in the forms in which the nitrogen is present in the potatoes that may show whether the nitrate applied, in this case at the rate of 800 pounds per acre, has had any influence in this respect. The average total nitrogenous constituents in our potatoes is somewhat higher than that given by Jenkins and Winton, still it does not reach 2.7 percent, so it is evident that we shall have to deal with relatively small differences, as according to this average the total nitrogen is 0.42 percent of the potato, but even this is nearly one-fifth higher than the average given by Jenkins and Winton.

THE FORMS OF NITROGEN IN POTATOES

	Total Nitrogen Percent	Amm. and Amid Nitrogen Percent	Amino Nitrogen Percent	Albumin Nitrogen Percent	Peptose Nitrogen Percent	Petene Nitrogen Percent	Nitric Nitrogen Percent
Early Ohio, check	0.4234	0.0638	0.0968	0.1255	0.0469	0.0138	0.0063
Early Ohio, 800-lb. $NaNo_3$	0.4301	0.0653	0.1020	0.1380	0.0451	0.0186	0.0075
Bliss' Triumph, check	0.4284	0.0545	0.0769	0.1434	0.0801	0.0004	0.0062
Bliss' Triumph, 800-lb. $NaNo_3$	0.4425	0.0587	0.0864	0.1831	0.0576	0.0174	0.0082
Rural, check	0.3702	0.0628	0.0988	0.1168	0.0484	0.0358	0.0004
Rural, 800-lb. $NaNo_3$	0.4333	0.0638	0.0900	0.1292	0.0461	0.0279	0.0025
Downing, check	0.4242	0.0584	0.0859	0.1335	0.0384	0.0096	0.0030
Downing, 800-lb. $NaNo_3$	0.4399	0.0683	0.1090	0.1586	0.0762	0.0270	0.0049
Pearl, check	0.3090	0.0561	0.0872	0.1176	0.0556	0.0188	0.0002
Pearl, 800-lb. $NaNo_3$	0.4130	0.0581	0.0856	0.1240	0.0846	0.0446	0.0013

In this table we find that the application of sodic nitrate at the rate of 800 pounds per acre has produced an increase in the total nitrogen present and has brought about changes in the relative amounts of the different forms in which it exists in the potato. Some things that we have said in preceding paragraphs concerning the checks as being unsatisfactory standards and the reasons for this must be considered in this connection. The checks themselves average high in total nitrogen, 0.418 against 0.342 for the average given by Jenkins and Winton, which is higher than others that I find; for instance, Langworthy is quoted by Stewart as giving the protein of potatoes as purchased as 1.8 percent which would correspond to 0.288 percent of nitrogen, which is much below our average check, 0.418 percent. The average for the total nitrogen for all varieties that received a dressing of nitrate at the rate of 800 pounds per acre is 0.431 or 0.013 higher than the average of those that received no application of nitrates. This difference is considerably in favor of the potatoes that received the application of nitrates in each of the individual pairs. The albumin nitrogen in the individual pairs is also consistently larger in those grown with the application of the nitrate. The same is true in the case of the amid and amino nitrogen, with two exceptions in the case of the amino nitrogen. So far as this series of samples is concerned, the most positive effect of the nitrate is shown in the amount of the nitric nitrogen. The maximum difference shows six times as much in those from the plot with nitrate as in those from the check plot. These results are, under the conditions, as decisive as one could expect; in fact, rather more so. It, however, is true, that the general characters and quantities of the nitrogenous constituents of these potatoes are so similar that they are not suited, in any measure, for the purpose that we grew them; i. e., to ascertain whether the application of these quantities of nitrates would so modify the composition that it would increase their susceptibility to disease and impair their power of resistance when attacked. This simi-

larity in composition is what we should expect since we find in July, August and the first half of September the nitrates ranging from 250 to 500 pounds in the top four inches of these check plots, with the exceptional result of over 1100 pounds for one of them. The samples were taken 14 days apart and always avoiding the more favorable conditions for the formation of nitrates. In these considerations we are tacitly assuming that there were no nitrates available to these potatoes other than those that we found in the surface four inches of this soil which cannot be true, and further, that there were no variations in the 14 days intervening between the dates of our sampling which is also almost certainly a false assumption. We applied our nitrate immediately after the potatoes were planted, and trusted to cultivation and irrigation to bring it within the feeding area of the plant. We tried to distribute it evenly over the whole surface. We do not know whether the time of distribution was the most favorable nor the proportion of it that ever became actually available. We were influenced in choosing the time of application and the amount applied by our observations on other crops. We found, for instance, that 250 pounds of sodic nitrate per acre applied to wheat at the time of planting produced incomparably larger effects than a further addition of 500 pounds during the season. Again, we found that from 800 to 1000 pounds produced the maximum deleterious effects upon a beet crop, but in neither of these cases did we have a continuous excessive supply furnished by the soil itself. In the case of the wheat crop, we had in the surface foot of soil in August, 1915, at the time of harvest, the equivalent of 19.5 pounds of sodic nitrate per acre, whereas the amount present in the check plots on which we grew potatoes was from 300 to 500 pounds per acre in the top four inches of soil for the month of August, 1920. The results obtained under these conditions are as great and as decidedly positive as we could expect and indicate clearly that the potato is, in regard to composition at least, sensitive to the effects of the nitrate that may be available. A further suggestion afforded by the preceding facts is that Greeley, owing to the character of its soil, is not the place where we may hope to obtain decisive answers to the questions to which we have addressed ourselves. As we shall present the data obtained in succeeding years, in a later bulletin, we defer further comment on this subject.

ASH CONSTITUENTS

In a similar study made on sugar beets and also on wheat, two very dissimilar crops, we found that nitrate of soda tended to increase the total ash, to suppress the phosphoric acid and to modify the quantitative relations of the different forms in which nitrogen is present. In the beet it raised the total nit-

rogen from 0.15 percent to 0.27 calculated on the fresh beet, and depressed the phosphoric acid, calculated on the pure ash, from 13.9 to 2.89 percent. Its effect upon the amount of potash present was generally to depress it. The pure ash of our standard beets carried about 52.5 percent of potash, and beets grown with nitrates from 29 to 38 percent. But when the potash is calculated on the green weight there is usually more in the beets grown with nitrate. The effects of nitrates on the ash of wheat was in the same direction but very much smaller, and increased the potash in the wheat plants.

NITRATES DEVELOPED IN OUR CHECK PLOTS

The data that we have obtained for potatoes are not very satisfactory because we have no data for what we may call standard potatoes for Colorado. It is true that we grew our checks for the purpose of having data that would show by comparison the effects of the nitrates supplied. Reference to the results obtained in determining the nitric nitrogen in the soil of these check plots makes it clear that we had in the top four inches of soil of these check plots throughout July and August nitric nitrogen equivalent to from 160 to 660 pounds of sodic nitrate per acre, taking the weight of this four inches of soil at 1,333,333 pounds. The samples of soil taken in May to a depth of one foot showed from 66 to 120 pounds. These samples were taken shortly after the land had been plowed to a depth of nine inches. As the results stand, it would have been better if we had taken samples in June and gotten an idea of the rate of increase in the nitrates between 20 May and 7 July, but during this period we took no samples. On 20 May, the average content of nitric nitrogen in the six samples of surface soil taken to a depth of one foot was 15.9 p.p.m. and on 7 July the average of the 15 samples taken to a depth of four inches was 25.2 p.p.m. This increase is suggestive of a very active nitrifying process, and it continued throughout the growing season so that our check plots were supplied with nitrates from a natural source equivalent to an application of at least from 300 to 500 pounds of sodic nitrate. Our applications made immediately after planting ranged from 200 to 800 pounds per acre. It is evident that under these conditions we can have only that increased effect of the nitrates that might be caused by the addition of these quantities to that produced by those naturally furnished by the soil, and this is true of all and each of the properties of the potatoes, including the growth, the susceptibility to disease, and composition of the vines as well as the composition, the keeping and cooking qualities of the tubers. Of course, our aim was to apply so much nitrate that we would produce an exaggerated effect, so much so that there could be no question about the cause of the effect produced.

We, on the other hand, assumed that our check plots would produce potatoes such as would be produced with only a small amount of nitrates,—less than 40 p.p.m. Instead of this, we find from 300 to 500 p.p.m. of these salts and in an extreme case 1122 p.p.m. This was not in a single sample but in a composite one made up of 20 sub-samples taken to a depth of four inches. Under these conditions one cannot deny the possibility that the checks may show a maximum effect of the nitrates in which event our whole series of experiments would be inconclusive. At the very best, the differences that we had hoped to obtain will be greatly reduced and the physiological and pathological differences that we had hoped to observe may have been wholly obliterated.

ASH OF POTATOES GROWN WITH AND WITHOUT APPLICATION OF SODIC NITRATE

VARIETY	EARLY OHIO		BLISS' TRIUMPH		RURAL	
Fertilizer Per Acre	Check	800-lb. $NaNO_3$	Check	800-lb. $NaNO_3$	Check	800-lb. $NaNO_3$
Air Dry	Percent	Percent	Percent	Percent	Percent	Percent
Dry Matter	21.70	21.20	19.60	20.11	20.80	20.30
Ash in dry matter	4.75	5.19	5.53	5.69	4.54	4.84
Ash in fresh potato	1.029	1.109	1.084	1.144	0.943	0.983
Moisture 200°C	0.481	1.027	0.881	1.343	0.713	0.901
Volatile above 200°C	4.249	2.160	3.284	2.897	2.625	3.749
Carbon	0.000	0.034	0.000	0.253	0.059	0.089
Sand	0.286	0.592	0.886	0.451	0.245	0.308
Silicic acid	0.716	0.940	1.107	0.708	0.979	0.745
Carbonic acid	13.560	14.570	13.380	14.380	16.440	17.220
Chlorin	3.170	2.901	3.601	3.462	1.983	1.875
Sulfuric acid	4.920	4.950	4.858	4.653	4.195	4.086
Phosphoric acid	14.880	13.656	13.901	13.356	12.526	11.233
Ferric oxid	0.192	0.183	0.199	0.268	0.190	0.163
Aluminic oxid	0.210	0.281	0.406	0.182	0.258	0.133
Manganic oxid (br)	0.060	0.061	0.037	0.028	0.047	0.023
Calcic oxid	1.492	1.517	1.557	1.602	1.236	1.716
Magnesic oxid	3.539	3.512	3.823	3.771	3.253	3.115
Sodic oxid	0.383	1.057	0.416	0.885	10.340	10.718
Potassic oxid	53.231	53.369	52.907	52.289	52.286	54.606
Sum	101.364	100.815	101.243	100.528	100.376	100.680
O equivalent to Cl	0.715	9.654	0.812	0.781	0.447	0.423
Total	100.649	100.161	100.431	99.747	99.929	100.257

ASH OF POTATOES GROWN WITH AND WITHOUT APPLICATION OF SODIC NITRATE (Continued)

VARIETY	DOWNING		PEARL	
Fertilizer Per Acre	Check	800-lb. $NaNo_3$	Check	800-lb. $NaNo_3$
Air Dry	Percent	Percent	Percent	Percent
Dry matter	22.600	19.550	21.400	21.600
Ash in dry matter	4.557	5.110	4.614	4.716
Ash in fresh plant	1.031	0.999	0.987	1.019
Moisture 200°C	0.443	0.380	0.134	0.296
Volatile above 200°C	2.682	2.552	2.661	2.155
Carbon	0.000	0.029	0.387	0.182
Sand	0.588	0.571	0.477	0.451
Silicic acid	0.958	0.870	1.000	0.968
Carbonic acid	16.610	19.020	17.980	18.720
Chlorin	2.048	1.721	2.102	1.934
Sulfuric acid	4.484	3.984	4.682	4.506
Phosphoric acid	11.601	10.637	10.664	9.673
Ferric oxid	0.225	0.185	0.201	0.228
Aluminic oxid	0.173	0.292	0.281	0.095
Manganic oxid (br)	0.083	0.058	0.071	0.057
Calcic oxid	1.862	1.967	1.253	1.528
Magnesic oxid	3.570	3.300	3.509	3.502
Sodic oxid	0.484	0.201	0.062	0.484
Potassic oxid	53.942	54.370	54.753	56.171
Sum	101.753	100.137	100.217	100.950
O equivalent to Cl	0.462	0.388	0.474	0.436
Total	100.291	99.749	99.748	100.514

OTHER ANALYSES OF POTATO ASHES

The few analyses of potato ash that I have found are not as full as one could wish and it is evident from what I have already said concerning the conditions under which our checks were grown that it would be wrong to consider them as representative of potatoes grown with a normal amount of nitrate available throughout their growing period. We see that the application of 800 pounds per acre of sodic nitrate shows the effect of this salt upon the amount of phosphoric acid and potash in the ash. The checks being regularly higher than the nitrate samples in phosphoric acid and lower in potash. The ash of the check samples are themselves lower than the averages given for the phosphoric and higher than those given for potash in potato ashes that I have found. In Leach's "Food Composition and Analysis" revised by Winton, p. 311, is given an average of 53 analyses taken from Koenig and presumably of German potatoes, which is as follows: Ash in dry substance 3.77, Potash 60.37, Soda 2.62. Lime 2.57, Magnesia 4.69, Iron oxid 1.18, Phosphoric acid 17.33, Sulfuric acid 6.49, Silica 2.13, Chlorin 3.11. I do not think that comparisons in this case are of much value, but it will be noticed that the ash in the dry matter, in our case air-dried, is much higher. Our average is 5.09 against 3.77. The phosphoric acid, P_2O_5, is decidedly lower,—our average for the ten samples analyzed even after the carbon dioxid, sand, and moisture at 200 deg. C. have been deducted, or in other words the pure ash, gives an

average of 14.57 against 17.33. The actual amount of phosphoric acid removed per 1000 pounds of our potatoes is greater than that removed by the German potatoes owing to the higher content of ash. The potash in the pure ash of our potatoes, as shown by the average of the ten analyses, is 65.12 percent against 60.37 percent for the German potatoes. As no facts are known about the soil, fertilization or varieties these comparisons have only a small and general interest.

AVERAGE PHOSPHORIC ACID AND POTASH IN POTATOES

I called attention in a previous paragraph to the effect of the nitrates applied on the phosphoric acid and potash in the ash of beets and wheat. The statement is made that it suppresses the former, and either has no effect upon or increases the percentage of the latter. These effects are as marked in the case of the potato as in either that of wheat or the sugar beet.

It may be well to mention the fact that we are comparing the fruit, in the case of wheat, at least for the most part, with parts of the plant in the cases of the beets and potatoes. We arrange the results obtained, calculated on the pure ash, in the following table:

PHOSPHORIC ACID AND POTASH IN PURE ASH OF POTATOES GROWN WITH AND WITHOUT NITRATES

		Phosphoric Acid Percent	Potash Percent
Early Ohio	Check	17.41	60.96
Early Ohio	800-lb. $NaNo_3$ per acre	16.29	64.45
Bliss' Triumph	Check	16.38	61.18
Bliss' Triumph	800-lb. $NaNo_3$ per acre	15.93	63.08
Rural	Check	15.16	63.45
Rural	800-lb. $NaNo_3$ per acre	13.77	66.95
Downing	Check	14.13	66.30
Downing	800-lb. $NaNo_3$ per acre	13.30	67.89
Pearl	Check	13.33	67.25
Pearl	800-lb. $NaNo_3$ per acre	12.09	69.73

The average phosphoric acid for the five check plots is 15.28 percent, that for the five plots receiving 800 pounds $NaNO_3$ per acre is 14.28 percent. The average potash for the same is 63.83 percent for the check, and 66.42 percent for those that received 800 pounds of nitrate.

The season of 1920 was an unfortunate one for us in that the vines were so badly damaged by a hail storm in August that we did not use them in our investigation. How much this affected the composition of the tubers I do not know, but preceding statements show that whatever these effects may have been, those of the added nitrates were not wholly concealed. The effect of the nitrates was, after all, the main object that we had in view. Still it was regrettable that the vines were so badly damaged.

SUMMARY

We obtained by our season's work a knowledge of the composition and deportment of the soil in which we were to conduct further experimentation. In this respect the main points were that the chemical composition was satisfactory, but the physical properties were disadvantageous. It was, however, the only land at our disposal.

The fixing and nitrifying capacities of the soil were found to be very considerable. The maximum increase in the total nitrogen in the surface soil on incubation for 40 days was 110 p.p.m., and in the subsoil 121 p.p.m.; the maximum increase in nitric nitrogen in the same time was 39 p.p.m. for the surface soil and 25 p.p.m. for the subsoil.

The average nitric nitrogen found in our western series, 9 checks, on 9 August was 66.1 p.p.m. taken to a depth of 3 to 4 inches, and in our eastern series, 6 checks, was 51.0 p.p.m. On 2 September, we found a slight falling off except in one check which had risen to 187.0 p.p.m., which was the maximum found in any check plot during the season. This was a composite sample made up of 20 subsamples.

The nitric nitrogen in top 3-4 inches of soil during July and August in the western series was equivalent to 286.8 pounds of sodic nitrate, and in the eastern series 141.4 pounds. These quantities represent a continuous supply of nitrates during these two months. We applied 200, 400, 600 and 800 pounds per acre at the time of planting, expecting to so exaggerate the effects of this salt that we might recognize it unmistakably.

In the study of this subject in the case of wheat, we found that 250 pounds per acre produced almost as large an effect as 750 pounds, though the 250 pounds were applied at the time of planting and the 750 pounds were added in three applications of 250 pounds each at intervals of four weeks.

Our western series had a continuous supply in the case of the check plots of 286.8 pounds in the top 3-4 inches during July and August, and on 16 September the average found for the check plots was 210.6 pounds for the same depth. Under these conditions there remained nothing for us to do except to find out if possible whether the application of 800 pounds of nitrate per acre at the time of planting had produced a big enough effect to be detected by analytical methods. The ordinary analysis of the tubers gave the following average results for the five varieties used:

	Water	Dry Matter	Ash	Fat	Protein	Crude Fibre	Nitrogen Free Extract
Checks	80.18	19.82	1.02	0.10	2.54	0.53	15.24
Nitrates	78.78	20.22	1.02	0.09	2.74	0.50	15.88

These averages are so nearly identical that only in the case of the protein can the differences be considered as falling outside of the analytical errors. This means that our check potatoes were typical nitrate potatoes, and that those grown with the addition of 800 pounds more nitrates were only a little richer in total nitrogen than those grown with the natural supply. The average protein in potatoes given by Jenkins & Winton is 2.14, and by Langworthy for potatoes purchased in the market, as 1.8 percent. These facts make clear the statement of a former paragraph, that our checks failed us almost completely.

When we come to study the distribution of the nitrogen in these potatoes, we find the same close agreement in the figures obtained which is a fact to be expected from the data already given. As there is but little nitrogen in the potato tuber, from 0.288 to 0.44 in the dry matter, there is not much for any one part when this is divided into six or seven parts, and a difference constantly in a given direction is more significant for us as indicating the effects of the nitrates than its amount, especially in view of the continuous and liberal supply of nitrates formed in the soil of our check plots.

Our attempts to determine ammonia nitrogen in the tubers of this crop were unsatisfactory. This may have been due, at least in part, to the manner of storage, but we have included it, if present, in the amid nitrogen. The other determinations are as satisfactory as the methods adopted justify us in expecting. The 800 pounds of sodic nitrogen increased all the forms of nitrogenous compounds determined, some of them relatively a great deal. The potatoes grown on our check plots all showed the presence of nitric nitrogen but in no case so much as those of the nitrate plots, in some cases only a sixth as much. The amino nitrogen is very much greater in quantity, and in two instances the check contained more than the nitrate plot, but in the other three pairs it was greater in the nitrate plot. The albumin nitrogen which was approximately 35 percent of the total was uniformly higher in those from the nitrate plots.

The average starch content of the potatoes from the checks and nitrate plots is practically identical; 14.51 for the check plots and 14.56 for nitrate plots. The individual pairs are, considering the difficulties of this determination, very close together.

The ash of our potatoes is rather high considering the small amount that usually occurs in the tubers. The average given by Jenkins & Winton is 0.95, and A. Mayer gives 0.39, presumably for German potatoes, while ours has 1.03 percent in the dry matter. The average phosphoric acid in the ash given by A. Mayer is 15.2, while the average for our ten samples of ash is 12.2 percent. This is the relative amount in the ash of the dry matter. The absolute amount removed by an equivalent of our potatoes is more than twice that of the German potatoes.

We found that the application of nitrates depressed the phosphoric acid but increased the potash in the ash of sugar beets, also in that of wheat. The same result is found again in the potatoe. It is true that we have no analysis of potato ash that we can consider standard; all that we can say is that our data prove conclusively that the application of 800 pounds of sodic nitrate per acre has depressed the phosphoric acid and increased the potash in the ashes of all varieties to a greater extent than the quantities that were available to the potatoes that grew on the check plots.

The indications are that the composition of the potato is radically modified by an excess of nitrates.

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HARDY VARIETIES OF APPLES FOR NORTHEASTERN COLORADO

By E. P. Sandsten

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HARDY VARIETIES OF APPLES FOR NORTHEASTERN COLORADO

By E. P. Sandsten

Commercial apple-growing in Northeastern Colorado is confined to the foothill area and to the river valleys before these emerge upon the plains. The foothill lands offer suitable sites in the way of protection against strong and drying winds and also in the matter of soil and air drainage. Winter killing is less frequent and damaging spring frosts are less apt to occur.

The planting of apples in these favorable areas began with the early settlement of the country some fifty years ago and many of the original plantings are still alive and producing fruit. With the development of irrigation and the settlement of the adjacent plains land, a few farmers planted orchards both for home use and for market. Most of these plantings have disappeared or are disappearing. A few orchards situated on favorable sites and given fair care are producing profitable crops. In moving eastward from the mountains onto the open plains, conditions become less favorable to apple growing, winter killing of trees occurs and destructive spring frosts are frequent; fewer farm orchards are met with and those found are in most instances unprofitable.

A few years ago the hortciultural department made a survey of the orchards in Northeastern Colorado, and this survey revealed the fact that early plantings were made without reference to their adaptation to the soil and climate of the region. In favorable localities many of the eastern varieties survived, but on unfavorable sites they soon died. Like all pioneer plantings, too many varieties were grown and naturally the majority were more or less worthless. In most cases the planters bought what the nursery agent offered or recommended, with little regard to their hardiness or market value. Too often substitutions were made by the nurseryman and the planters never knew what they were growing until the trees fruited. The wonder is that so many trees survived. The apple survey showed more than 50,000 apple trees in commercial plantations in Larimer County and not less than fifty-eight varieties. So far as the number of varieties is concerned, Larimer County is second in the State; Fremont County heads the list with ninety varieties. It is safe to say that ten or possibly twelve varieties out of the fifty-eight are worthy of consideration in commercial planting in this section.

OUTLINE OF THE EXPERIMENTAL ORCHARD

In order to gain more accurate information on the question of hardiness and adaptability of the different varieties of apples, a trial orchard was planted on an open, exposed piece of land located about four miles and a half east of the foothills. The land had previously been used for various agricultural crops under a system of rotation. It was in a good state of fertility, medium-heavy loam, well drained and in general, so far as soil is concerned, well adapted to apples. The lay of the land is not the best, as the surrounding land is level and no protection is afforded in the form of natural or artificial windbreaks. Since the object of the experiment was to determine the hardiness of a number of varieties of apples and not the development of commercial orchards, the site chosen was such as one might expect to find on most farms on the plains.

The land was fall plowed to a depth of eight or nine inches and left in a rough state during the winter. In the spring it was pulverized and marked out for planting. The trees were set in squares twenty feet by twenty feet. Yearling trees, that is one year from grafts, were set. The trees were obtained in the Northwest and in the Southeast. They were planted in the usual way and irrigated immediately after planting. Practically every tree grew. The list includes the standard commercial varieties that are grown in the West, together with a number of hardy varieties grown in the upper Mississippi Valley. The following varieties were secured for the experiment:

VARIETIES PLANTED

Gano, McIntosh, Red Astrakan, Jonathan, Grimes, Patton's Greening, King, Stayman, Rome, Delicious, Chenango, Wagner, Wealthy, Gravenstein, Spy, Wolf River, W. W. Pearmain, Hyde's King, Ben Davis, Alexander, Sheriff, and Northwestern Greening.

The planting was done in the spring of 1914 and the trees were given intensive culture thruout the growing season. During the middle of May, 1915, an inventory was taken of the orchard to determine the percentage of dead trees, with the following results:

	Percent.
Gano	40
McIntosh	37
Red Astrakan	35
Jonathan	40
Grimes	65
Patton's Greening	25
King	83
Stayman	80
Rome	90
Delicious	50
Chenango	40
Wagner	90
Wealthy	0
Gravenstein	45
Spy	60
Wolf River	0
W. W. Pearmain	80
Arkansas Black	60
Hyde's King	50
Black Ben Davis	40
Alexander	55
Sheriff	35
Northwestern Greening	30

The percentage is based upon the number of trees killed to the ground either above or below the graft. Where the die-back was below the graft the trees were removed. Where the killing was above the graft, they were permitted to remain and in almost every case a new tree was produced during the growing season. In every instance the roots were found to be alive, the injury being entirely confined to the tops. The dead trees were removed and new ones substituted. An inventory was taken in May, 1916 with the following results, based upon the percentage of dead trees of the original planting:

	Percent.		Percent.
Gano	45	Wealthy	10
McIntosh	40	Gravenstein	50
Red Astrakan	50	Spy	100
Jonathan	50	Wolf River	20
Grimes	100	W. W. Pearmain	100
Patton's Greening	40	Arkansas Black	70
King	100	Hyde's King	60
Stayman	100	Black Ben	50
Rome	100	Alexander	65
Delicious	60	Sheriff	45
Chenango	55	Northwestern Greening	35
Wagner	100		

During the summer of 1916 the trees again made a satisfactory growth, tho considerable injury resulted from sun scald on the west and southwest sides of the trees. Some damage was also done by the strong northwest winds to which the trees were freely exposed.

In the spring 1917 an inventory was again taken of the orchard, with the following results, based upon the total number of trees dead of the original planting:

	Percent.		Percent.
Gano	50	Wealthy	20
McIntosh	45	Gravenstein	65
Red Astrakan	60	Spy	100
Jonathan	55	Wolf River	45
Grimes	100	W. W. Pearmain	100
Patton's Greening	60	Arkansas Black	95
King	100	Hyde's King	70
Stayman	100	Black Ben	60
Rome	100	Alexander	55
Delicious	65	Sheriff	50
Chenango	70	Northwestern Greening	40
Wagner	100		

As in previous years, the winter killing extended only to the top. In cases where the winter killing did not extend below the graft, new trees had developed from sprouts and made considerable growth during the summer, but only to be killed again during the following winter. A number of trees that had repeated this process for three or four years developed a gnarly

trunk at the base, which, due to the numerous cut-backs, did not form a satisfactory trunk, and were to all intents and purposes worthless for commercial orchards and were counted as dead.

In the replanting of 1916 two-year-old trees were used to test their hardiness in comparison with one-year-old trees as used in the original planting. The result of this comparison will be discussed later.

No replanting was done after 1917 but the orchard was maintained and cared for in the usual manner until the spring of 1922 when a final inventory was made.

Percentage of live trees from the original planting:

	Percent.
Gano	45
McIntosh	55
Red Astrakan	35
Jonathan	45
Grimes	0
Patton's Greening	30
King	0
Stayman	0
Rome	0
Delicious	30
Chenango	25
Wagner	0
Wealthy	75
Gravenstein	30
Spy	0
Wolf River	50
W. W. Pearmain	0
Arkansas Black	5
Hyde's King	20
Black Ben	35
Alexander	40
Sheriff	45
Northwestern Greening	45

The death rate after the third winter was relatively small, the losses being in many cases due to sunscald and to frost injuries received during the first two years after planting. There is little doubt but what a windbreak of some kind would have materially reduced the losses.

CONCLUSIONS

An analysis of the results shows that winter killing is most severe during the first year after planting, the losses being relatively small during the subsequent years. The high mortality of the first year should be attributed to the succulent condition of the wood which offered less resistance to the dry winter weather. The varieties which survived after 1918 continued to grow and a few fruited during the season of 1917 and 1918 but no record was kept of the fruiting. After the trees had survived the second and third year, the mortality was small and in general comparable to the average mortality that occurs in commercial planting on the better sites. Winter examination of the trees showed conclusively that the killing was due to dry winter weather so common to the plains area. The branches and twigs were in many instances badly shriveled and dry. These would plump up during a spell of moist weather.

A study of climatological conditions during the period of this experiment showed some difference both in precipitation and temperature but not enough to warrant a conclusion that

weather conditions during this period were unusual or that the mortality of the trees was due to unusual weather conditions. In fact the winter temperatures were not lower than in many of our commercial apple-growing sections where many of the more tender varieties are grown successfully. The precipitation on the plains during the winter is, however, small, and bare winters are frequent. The atmospheric humidity is low and drying and severe winds are frequent.

In no case did the winter killing extend to the roots of the trees and the question of hardy stock does not enter into the problem. The experiments show conclusively that the main cause of winter killing of apple trees on the plains is due to the drying effect of our winter climate.

It is evident that yearling trees generally used in planting commercial orchards are more apt to winter kill during the first winter than older trees.

In the replanting of 1916, two-year-old trees were used, the object being to test the relative hardiness of these as compared with yearling trees. **The results show conclusively that the two-year-old trees are better able to withstand the dry winters and the mortality among them was fifty percent less than the yearlings.** The wood is harder and more mature and thus better able to survive the first winter and only on very favorable sites should yearling trees be planted.

SUGGESTIONS FOR GROWING APPLES ON THE PLAINS

Commercial apple-growing on our eastern plains should not be encouraged. The planting should be confined to the home orchard and on the most favorable sites obtainable. Only the hardier varieties should be planted. Where natural shelter in the form of hills is not obtainable, windbreaks, planted at least two or three years before the planting of the orchard, should be used. The windbreak will greatly modify the effect of our strong winds and protect the trees from their effect. Where irrigation is not possible, a heavy mulch should be provided so as to retain all the available moisture in the soil for the use of the trees.

Two or three-year-old trees should be planted instead of yearling trees. The wood on such trees is more mature and harder and better able to survive the first winter after planting. Care should be taken in selecting trees that have a well-formed head and are headed low. Low branching will protect the trunk from sunscald. Low-headed trees are preferable to high headed; they are easier to spray and it is more convenient to pick the fruit.

The trees should be set at the same depth that they were in the nursery, at most not more than one inch deeper if the soil is light. A thoro preparation of the land before planting

is important. The land should be fall plowed to a depth of ten inches and left in the rough during the winter. A thoro harrowing is all that is necessary in the spring before setting the trees and the trees should be set in squares twenty-four feet by twenty-four feet. Closer planting is not advisable.

The holes in which the trees are set should be sufficiently large to accommodate the roots without crowding and all broken or torn roots should be cut off. If the soil is dry, irrigation should follow immediately. This will settle the soil around the roots and hasten the growth of the trees.

After planting, the tops must be pruned to correspond with the greatly reduced root area. From one-half to two-thirds of the previous year's wood should be removed but care should be taken to keep the tree in balance. Subsequent pruning should consist in heading back the top to keep the bearing wood as low as possible. The general practice of pruning from the bottom upward should be reversed.

Cultivation should alternate with some cover crop to keep the soil supplied with vegetable matter and keep the trees in a healthy growing condition. Liberal applications of barnyard manures should be applied during the period of clean cultivation. It should be applied in the fall of the year and plowed under before winter, followed by clean cultivation during the following summer. In general a crop of biennial sweet clover should be planted the following year and cut and left on the ground. The second year the first crop should be cut and left on the ground and the second crop plowed under in the fall while still green. This will make a four-year rotation, two in clean cultivation with a dressing of stable manure between and two years in sweet clover. The orchard should not be used as a pasture for livestock.

Systematic pruning, thoro cultivation, careful spraying and irrigation are essential for profitable production. Most farmers manage to grow apple trees for shade but few make any serious attempts at raising apples.

Irrigation.—The trees should be given two or more thoro irrigations during the summer, particularly during the fore part. Irrigation should cease in August so as to slow up the wood growth and enable the tree to mature the wood before winter. If irrigation is continued late into the fall the young trees will continue to grow until killed by frost, resulting in soft and succulent wood, which is more easily injured by the subsequent dry weather. Where water is available in late fall or early winter, the trees should be given a thoro irrigation after the leaves have fallen and the trees entered into a dormant stage. This will fill up the soil as well as the trees with moisture, thus enabling the trees to go through the winter in a better condition than if left dry.

The following varieties have proved the hardiest and are well adapted for planting both in more or less exposed situations, as well as in more favorable ones:

Summer apples	Yellow Transparent Duchess
Fall apples	Wealthy Northwestern Greening
Early Winter apples	McIntosh Jonathan Delicious
Winter apples	Smith Cider Black Ben Sheriff

For exposed places it is not advisable to plant the Jonathan and Delicious, but with windbreaks of some kind, they will prove a success.

The following supplementary varieties have succeeded but are not recommended unless for strictly family use:

Red June	Wolf River
Red Astrakan	Walbridge
Alexander	Geniton

The list could be further extended, but nothing is gained in planting a large number of varieties.

Number 293 September, 1924

BACILLARY WHITE DIARRHOEA OF CHICKS

By I. E. NEWSOM



Testing Blood in the Laboratory Gives Definite Results.

COLORADO EXPERIMENT STATION
Agricultural Division
Fort Collins



Making the incision at the point where the vein passes over the first joint away from the body.

BACILLARY WHITE DIARRHOEA OF CHICKS

Dr. I. E. Newsom, Veterinary Pathologist

Economic Importance.—With the growth of large hatcheries and the selling of day-old chicks, white diarrhoea has become a very serious malady within the State. In many instances during the past year, from 90 to 95 percent of all the day-old chicks received by certain poultrymen and farmers have died within the first week after their arrival. Literally thousands have succumbed to this malady until many people hesitate to buy baby chicks under any circumstances. This condition calls for remedial measures which it is the purpose of this paper to set down.

Geographical Distribution.—The disease exists practically wherever chickens are raised, but manifests itself particularly where large numbers are gathered together, since, under these conditions, it is more easily spread. As long as chickens were raised on farms in small flocks and eggs were hatched under hens little difficulty was experienced, but now that large hatcheries handle thousands of eggs and ship large numbers of baby chicks the disease has been spread to all parts of the country.

Cause.—The disease is caused by a micro-organism belonging to the colon typhoid group and named *Bacterium pullorum*.

Transmission.—As far as our information goes the organism lives for only a short time outside the body of the bird, consequently it is necessary that adult chickens carry the organism within their bodies, thus constantly serving as a source of infection to other chickens. It has been determined that the organisms are largely carried within the ovary of affected hens, and that such hens lay eggs a considerable percentage of which contain the infection. Consequently, chicks are in many instances infected before they are hatched. Such chicks not only contract the disease themselves, but their droppings spread it to others in the same brooder.

As chicks seem to be most susceptible during the first four days of life, if they can be raised free from the disease beyond this time they are not likely to contract the infection. There are, then, two sources of infection. The hen transmits the disease to the chick

through the egg and the chicks transmit it to each other during the first four days of life. Whether the adult chickens transmit the disease to each other is a point that has not been fully determined, but for purposes of control we assume that they do.

Symptoms.—Chicks a few days old appear sleepy and dull, do not eat and their wings droop. They huddle in a corner as though chilled, show a whitish discharge from the bowels that "pastes them up behind," finally become paralyzed and usually die within two or three days after showing evidence of the disease. The disease spreads very rapidly so that it not infrequently happens that 80 to 95 percent of a given lot of baby chicks will die within a week after their arrival. Those that survive are often stunted, but even those that do get well are apt to carry the organism in their bodies and spread it to others.

Diagnosis.—The disease may be diagnosed partly from the symptoms but, since chilling, overfeeding, and possibly other factors will cause illness simulating diarrhoea it is not safe to make the determination on symptoms alone. An examination of the dead chick will reveal the yolk sack still unabsorbed. Where an accurate determination is to be made several chicks should be sent to the nearest experiment station for determination. Most State experiment stations make the diagnosis by culturing the organisms, which may take several days. However, the isolation of the organism gives the only posi-



Compare the ovary of a normal hen with that of an infected bird.

tive determination of the condition. In hens the chief means of diagnosis is by means of the ovary in which it will be found that the newly formed eggs are misshapen and discolored; the color varying all the way from yellow to green. Occasionally older birds also show infection of the peritoneum and the sac around the heart, in which case there will be grayish deposits on these membranes. However, even in these cases the diagnosis should be made by cultural methods to insure accuracy.

Treatment.—All affected chicks should be destroyed as quickly as possible as it is very rare for one to recover, and as long as they are living they are a constant source of infection to the other birds. It is better to take the well chicks and put them into entirely new surroundings, since it is very difficult to disinfect the houses and brooders satisfactorily. When the well chicks have been moved away from the old surroundings they should be constantly watched and any sick ones should be immediately removed and destroyed. The infected brooders should then be thoroughly washed with hot water to which lye has been added and should finally be sprayed with a strong disinfectant, such as a 3 percent compound cresol solution. (Cresol solution can be obtained at any drug store.) The well chicks should be given sour milk, but no system of treatment nor of diet will prove satisfactory in this condition.

Control.—Control consists usually in the elimination of the infected hens since these are the ones that keep up the infection. The determination of infection in hens is best made by means of the agglutination test, which is a test made in the laboratory by the use of the blood serum from the suspected birds. In order to run this test a small sample of blood must be furnished from each hen. The hens should be marked in such a way that they can be located after the result of the test is known.

Equipment for drawing blood—

A small, thin, sharp scalpel
One-half dram sterile vials with corks
Absorbent cotton

Procedure.—The hen is held between the legs or by an assistant. The wing is drawn away from the body, and with the sharp scalpel the vein is cut at the point where it passes over the first joint away from the body. It can be cut lengthwise or crosswise without any serious damage. It requires no antiseptic precaution and no water or other fluid should be used on the area either before or afterward. Even a drop of fluid in the blood will ruin it for testing. The blood is caught in the vial until the vial is approximately half full. The



Half a vial of blood is caught for the test.

vial is then corked and laid on its side to allow the blood to clot. The hens should be leg banded and the number on the leg band placed on the vial. If the blood is still flowing freely from the wound a little pledget of cotton can be pressed over it, and held for a few seconds. This will usually stop the flow. The scalpel should be wiped with cotton between birds. As soon as the bleeding is finished the vials should be placed on ice unless they can be shipped at once to the laboratory. They should be well packed and, if in the summer time, should be iced if they must go any considerable distance. Great care should be given to see that the blood gets to the laboratory in good condition, as otherwise the tests cannot be run or, if run, give erroneous results. For the present the laboratory of Veterinary Pathology of the Colorado Agricultural College will run these samples free of charged.

On receiving the reports, all birds reacting to the test, including the male birds as well as the hens, should be eliminated from the flock and preferably sold for slaughter. If more than 25 percent are infected with the disease it is usually better to dispose of the whole flock and start with fresh stock. The test should be carried out annually in flocks where the infection exists, preferably in the fall after the birds have been culled. Where it is desirable to rid the flock of the disease quickly, it may be advisable to test every six months. Experience shows that testing at irregular intervals is unsatisfactory.

Results of Testing.—In eastern states, where the work has been carried on longer than in Colorado, the improvement both in hatchability and livability of chicks has been very marked. In one flock in Massachusetts, consisting of 1,110 breeding birds, only 15 percent of the chicks hatched from the eggs matured in 1919. In 1922-24, after the flock had been freed from the disease, out of 11,600 eggs 8,700 chicks were hatched and 92.9 percent of them lived, showing very conclusively the benefits to be derived from freeing flocks from this disease.

During the past year the laboratory of Veterinary Pathology of the Colorado Agricultural College has received twenty shipments of blood for testing. Out of 1,394 samples tested there were 314 reactions or 23 percent. In only two instances were entirely negative results obtained and in one of these only nine samples were furnished and in the other only six. This would seem to indicate that the disease is quite widespread in Colorado.

Accredited Flocks.—The State of Illinois seems to have taken the lead in officially accrediting flocks. There the work is in the hands of

the state veterinarian who issues the accreditation and supervises the control. The licensed veterinarians in the state draw the blood and leg-band the chickens for which they are allowed a fee of 5 cents per bird. The samples are sent to the State University, where tests are made for an additional fee of 5 cents per sample. The culling is then done by the veterinarian who draws the blood. After two negative annual tests the flock is accredited, providing the owner signs a contract to follow the hygienic regulations set down by the state veterinarian.

In other states some accreditation work has been done, but as far as our information goes, no other state department has taken it over as has been done in Illinois. In some places the accreditation is under the direction of an association of poultry raisers, which organization appoints one or more men to draw the blood and cull the flock. In practically all cases the testing is done at the State Laboratory.

Owing to the seriousness of this disease it seems reasonable to believe that in a short time neither eggs for hatching nor baby chicks can be sold, except from flocks known to be free from infection.

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SOME ORCHARD CONDITIONS AFFECTED BY ARSENICALS, MARLS AND OTHER FACTORS

By Wm. P. Headden

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SOME ORCHARD CONDITIONS AFFECTED BY ARSENICALS, MARLS AND OTHER FACTORS

By Wm. P. Headden

This Station has issued two publications on the "Arsenical Poisoning of Fruit Trees," one in 1908 and the other in 1910. These publications are no longer available. In addition to these, the writer published in 1910 an article on "The Occurrence of Arsenic in Soils, Plants, Fruits and Animals,"* but no presentation on this general subject has issued from this source since that time.

Recently my attention was called anew to the rapid disappearance of our apple orchards, due to troubles resident in the soil. On investigating the matter a little, I find it true that whole orchards are sick and a great many trees in other orchards are abnormal, namely, the leaves are small, poor in color, often so curved as to be gray and woolly in appearance; the growth is small, the bark yellowish to yellowish red, and the trees lack thrift in general. This difficulty, together with untoward conditions have led to the removal of many orchards. The measure of this difficulty in a certain district was given to me in terms of the number of trees dug up in the spring of 1924, which was 110,000. A visit to this district, one with which I have been familiar for 25 years, left a very depressing impression upon my mind, as the remaining orchards show that, without doubt, the end is not yet, and I doubt whether more than a very few especially well-cared-for and favorably located orchards will remain after a very few years.

SPRAYING HAS KILLED ORCHARDS

The factors that have brought this condition to pass are of several sorts. I suppose that, in order of time, the use of arsenite of lime and Paris green, in combating the codling moth, was accountable for the death of a great many trees, as it caused acute arsenical poisoning by corroding the crowns and sometimes the bark under the bands used to trap the codling moth larvæ.

NITRATES CAUSE GREAT LOSSES

This was serious enough, but it was not comparable to the intensely destructive and wholesale action of the nitrates that developed in the soil. This was true not only of this but also of other sections. I have seen from a few isolated trees to acres of orchards killed outright by this cause in a single season.

The use of arsenite of lime and Paris green ceased years ago, and lead arsenate, a much more slowly acting poison, took their place; but the

*Proceedings Colorado Scientific Soc. Vol. IX, pages 345-360.



Plate 1.—Ganos, the same orchard as Plate 3 but on marly soil.

formation of nitrates in injurious quantities has continued and has been the predominant cause for the sudden death of very many trees. I have seen hundreds of them this season that have perished, due to this cause.

In Bulletin 157, published in 1910, I laid great stress on the slower action of arsenic under the term "systemic poisoning" and adduced a number of facts which are cogent today, just as they were 14 years ago. In the meantime, the trouble has run its course and the results are as given in the statement that the trees are in a dying condition, and 110,000 of them were removed in the spring of 1924, due to all causes.

ECONOMIC CONDITIONS HAVE AFFECTED ORCHARDISTS

It would scarcely be proper to leave this statement without mentioning some economic features that have made the orchardists willing to remove whole plantations. The principal of these economic features is the greatly increased difficulty in combating the codling moth. It has become necessary to spray more frequently and it is customary to use more arsenate of lead, thus greatly increasing the cost of operation, and yet the results obtained are very unsatisfactory. The prevailing low prices for apples, the high cost of labor and transportation, in fact of everything that goes into the production and marketing of a clean crop, have made the industry an unprofitable one for several years past. These economic features, added to the condition of the trees, account for the removal of the orchards.

As far as stated, the facts show that one should rather leave the story untold than make any comments on the conditions which are sad enough without the telling, and were there not some further object it would be wise to let it all pass, as we do no good to dead trees nor mend the losses that have been suffered.

It is now at least ten years since my attention was called to some peculiar facts pertaining to cherry trees. The trees would come out into full leaf, blossom freely and set an abundance of fruit. The foliage lacked color and substance as was pointed out to me by a carefully observing owner, who, in the early part of the season, could designate with accuracy the deportment of the tree during the season and its death as the fruit began to ripen. I did some work on this subject but it became necessary for me to devote my energies to another subject, so that the investigation was laid aside and has not been taken up again. In the meantime, a great many cherry orchards have been given up; the loss of bearing trees was too heavy and the industry has not flourished. I think that it has gone back materially in that section.

NITRATES KILL ORCHARDS

It would seem that there is a common cause for these failures. In this I may be mistaken. In any event, the problems are involved and may be similar only in part. Apple trees may die suddenly. I have seen the leaves wilt and droop within 24 hours and the tree never

revived. The cherry trees give definite signs of their impending death, but it finally comes suddenly and the leaves and half-ripe fruit remain clinging to the tree. We ascertained in the case of the apple trees that the cause of death was nitrates. The salt experimented with was sodic nitrate, but the salt usually present in the soil is calcic or magnesic nitrate. In one of the cherry orchards we found calcic nitrate. In the apple orchards the nitrates were general thruout an area of an acre and a half, or more; in the cherry orchard they occurred in spots, and, as a rule, in much smaller quantities than in the apple orchard, but in a few spots they were very abundant, equivalent to 3.2 percent of the surface soil. The significance of such spots should not be exaggerated; they do, however, show that this soil, under favorable conditions, can give rise to large quantities of these salts, which, of itself, is an important fact. We dug up several dying cherry trees to see if we could find any lesions that might lead to the recognition of the cause of the trouble. The large roots were already darker than those of vigorous trees, but beyond this they were perfect and gave no hint of trouble. The fibrous roots were dead and we did not succeed in finding a single living terminal or spongiole on such roots, but on the roots of living, healthy trees they were, of course, present. This was the only difference that we could find between the dying and healthy trees. The whole root-hair region of the dying tree had been destroyed and the tree collapsed. How long it had taken to effect this destruction, or at what period prior to the death of the aerial portion of the tree it had been effected, we do not know. The agent that effected this killing of the roothairs seems to have been calcic or magnesic nitrate, probably the former.

From results obtained on analysis of these soils, we are led to infer that the cherry tree is very susceptible to the action of these salts. It must be remembered that our soil samples were taken after the trees had been killed, while the damage had probably been done some months before.

The immediately active agent is, in this case, probably the nitric acid, for sodic nitrate produces very similar results in the apple tree. We are entirely in the dark in this case as to the possible action of the calcic oxid, though I cannot believe that it is really beneficial; on the contrary, I believe that in many cases it is actively deleterious.

The case of our apple trees is comparatively complex. We have had in the past many instances of the corrosive action of arsenical compounds on the trees. This we do not wish to consider, as it is very different from the cases that we wish to present, insofar as we can, for the details of the case lie beyond the province of the analytical chemist.

The effects of nitrates on the apple trees are violent and evident; at least the effects of which we take note are. They kill the tree outright and that quickly, with signs of physiological drought. The leaves may burn at the tips and edges or wilt and droop with as good as no warning, and in either case the trees die in a few days. The whole moisture-supplying apparatus of the tree is suddenly cut off, and the tree dies and it has no recuperative power. It may use up its small

amount of reserve material in an attempt to continue its existence by putting forth a few yellowish white leaves, or make a scattering display of bloom in the late fall, but such is its last effort and it dies. We believe this to be due wholly to the nitric acid group, but we do not deny the possibility that the lime may play a part. In fact, I believe that the lime does play a part, but that its action is so much slower than that of the nitric acid, and so much less striking, that it is negligible in such cases as have been mentioned. The action, at least the violent and fatal action of nitrates on our apple trees, is readily recognized, but any action that the lime may have is evidently very slow and of an entirely different character.

"SYSTEMIC" POISONING

In Bulletins 131 and 157 of this Station, I cited many cases of the acute corrosive action of arsenical compounds on apple and pear trees, but insisted in both bulletins upon another phase of its action; i. e., systemic poisoning, and suggested that not only the arsenic but also the lead and copper might act in this way. It was evident at that time, now 14 to 17 years ago, that very many of our orchards were in an unhealthy condition, and there was no evident connection of this conditions with the acute corrosive action of the arsenicals. Some of the reasons for this view, assigned at that time, were: The small size of relatively old trees, the lack of thrift, the color of the trunk and limbs, the splitting open of the bark, and the bleeding, both from these cracks in the bark and from wounds made by pruning. Further, this bleeding was accompanied by the deposition of incrustations and the formation of stalacitic deposits of an unusual character. They were very rich in lime and arsenic. They contained 25.0 percent of lime and 49 p. p. m. of arsenic acid.

MARLY SOILS NOT GOOD FOR ORCHARDS

Observation had already shown that our marly soils—this term "marly soils" included gypsum, sometimes mixed with lime carbonate and sometimes nearly pure—are not good for apple trees. The trees grow for a few years and begin to fail; the leaves are lacking in number, color and substance, and rosetting is common. The bark of both limbs and trunk is yellow or reddish yellow in varieties that should not show such a color, and they are short lived.

An early experience with such an orchard remains very clear in my memory. The trees corresponded to the above description, a few of them being just about dead. I had such a tree dug up. Its roots were externally black, they were brittle and did not have development enough to support the tree. The surface soil was very shallow and underlaid by a thick deposit of marl. The roots had not penetrated this.

Two questions presented themselves; one of starvation, the other of poisoning. Both were evidently playing a part, for the application of manure ameliorated but did not obviate the trouble.



Plate 2.—A near view of the best tree shown in Plate 3.

A later experience was very similar. In this case the root system of the trees was so feebly developed that I had a 16 or 18-year-old tree pulled over by a two-horse team without cutting a root. The roots were, as in the other case, outwardly black and brittle, and had neither depth nor size. Fertilization and deep plowing benefited the orchard but did not obviate the evil.

I know at this time of other orchards that are the duplicates of these. There is one section of country where I saw a good many acres of apple trees that had been set for perhaps three years and they were dead. On inquiring for a cause, I received the answer that they had been killed by "gyp." This may not have been the real cause, but it was the opinion of the people that gypsum was the cause. These trees had been dead too long to tell anything more about them than that they had been apple trees.

PROBLEM IS VERY COMPLEX

The question relative to the dying of orchards are, then, not simple. We have at least two possible causes for their death that are evident, nitrate and poisons applied to the trees and land in spraying operations, which may act locally at the crown of the trees or under bands corroding the bark. We have, in Bulletin 131 of this Station, designated this as acute irritant poisoning.

ROOTS ABSORB ARSENIC

This effect is greatly exaggerated by the absorption of sodic arsenite by the roots, when the tissues are blackened and destroyed very quickly. How quickly the destruction of the bark and wood follows the absorption of the poisonous solution I do not know, but the death of the affected parts is very quick. In one instance, the testimony of the owner and his family was that it followed within 15 minutes after the application of the solution. I saw this case within a few weeks of the application and the roots were then dead and blackened. In this case the arsenite had been applied to some small stumps to kill them, and on subsequently irrigating the ground the injury was done to the apple trees. We do not have such concentrated solutions of arsenic in the soil, and when the arsenic is obtained from this source the amount is small, insufficient to produce such intense results. We also have another type of poisoning which expressed itself in another manner and only slowly, I used the term systemic poisoning to designate this.

SPRAY BASES ALSO FOUND IN WOOD

The effects of the bases with which the arsenic was combined when applied to the trees and soil were also suggested as possibly harmful. No difficulty was experienced in proving the presence of copper and lead in the wood of these trees after the bark had been carefully removed to insure us as far as possible against obtaining any particles of spray materials.



Plate 7.—Healthy Gano



Plate 4.—A near view of one of the Canos.

Many of these orchards were set in land containing our so-called alkalis and their action on the spray material, especially lead arsenate, was considered. It was shown experimentally that they convert the arsenate of lead into soluble compounds. It was also shown that water actually extracts arsenic from these soils. These are the facts, though lime and iron salts are present in the soil. Mr. McDonnell of the U. S. Department of Agriculture, subsequently showed that sodic chlorid, which is as good as always present in soils, converts the lead arsenate into a definite chloro-arsenate with the removal of arsenic acid. The arsenic compounds are then not insoluble and the arsenic may be absorbed from the soil by the trees; at least the solubility of the arsenic would permit that they should do so.

ARSENIC FOUND IN ALL PARTS OF TREES

We demonstrated that they actually do take up arsenic, by collecting the dried juice that issued from wounds under conditions that made it very improbable that it should in any way be contaminated, and found the arsenic very abundant. We also gathered leaves and fruit from trees that had not been sprayed that season and found arsenic in them. The arsenic could reach the fruit only through the juices of the tree and must have been in solution in the tree.

That the arsenic came from the soil was shown by the sap of a tree that was cut off below the limbs, within two feet of the ground, and by the study of an elm tree which suffered from arsenical poinsoning, due to its roots feeding in an orchard which had been sprayed.

There is a question whether this systemic poisoning is caused by arsenic alone or is caused by the joint action of lead and arsenic or copper and arsenic. The thriftless condition of many orchards testifies to the fact that something is seriously wrong at this time and the removal of so many trees is proof that the owners' judgment is that the contest is lost.

It has taken 20 to 30 years to demonstrate this. Seepage has not contributed any significant part to this condition; alkali may have contributed in the manner specified, i. e., by reacting with the arsenical spray material used—but not because of the harmful quantity of white alkali in the sod. Nitrates have contributed very largely to the general result, and the greater part of the remainder has been caused by the systemic poisoning of the trees by the spray material absorbed from the soil, causing the evils complained of, summed up in the general expression that the trees are sick, which is fully equivalent to saying the trees are dying.

In both of the bulletins 131 and 157 referred to, published respectively 16 and 14 years ago, the writer insisted on another, in many cases a vital point, namely, on the effects of marl or carbonate of lime.

VIRGIN SOILS CONTAIN ARSENIC

In this connection it was shown that our virgin soils—this marl, and the gypsum that is of frequent occurrence as a deposit at varying, but shallow depths, under very many, if not most of our soils—contain

arsenic, and from this source arsenic may find its way into all plants, into potatoes, oats, grass and hays, into the flesh of our beef animals and into our own bodies. The writer used himself and two of his assistants to prove the latter. I am here and the assistants are still with me.

There is, then, another phase to the question pertaining to the thrift and life of our orchards, not universal, it is true, but which is present in very many orchards. This phase includes the occurrence of marl near the surface which contains arsenic; and a second feature is the relation of this marl to the fixation of nitrogen and to nitrification. It is not our intention to consider the latter subject to any extent in this connection, perhaps incidentally, as in some instances these two features have been found so intimately associated that they could not be mistaken.

It is as good as impossible to separate the effects of lime from those of arsenic, as all of these marls and this sort of gypsum that I have tested have contained arsenic. The best that I can do will be to compare trees growing in fairly deep soil with others growing in marly soil, some of them of the same variety in the same orchard, all sprayed and otherwise treated alike, and attribute the differences to the effects of the marl or lime. These differences are easily summed up; the former trees are well grown, vigorous, healthy and freely bearing trees, the latter are dying or already dead. The difference in age is one or two years, the larger, healthy trees being the younger. They are set the same distance apart in the rows. Plates 1 to 5 show the condition of the trees in this orchard.* Plates 6, 7, 8 and 9 represent another orchard.

These trees do not show ordinary chlorosis, though this malady sometimes appears in orchards at about the age of six or seven years, but it is another affection or is a different expression of the trouble. It is characterized by dwarfishness, yellowish red to yellow bark and a general lack of thriftiness. I have seen the twigs in the springtime so red that, at a distance, they looked like a peach, rather than an apple orchard.

As far as I know, the systemic action of lead, copper and arsenic on trees has not been recorded, and I suppose has not been made out. Many trees on these marly soils bleed rather badly in the spring of the year from old wounds or from cracks in the bark. A sample of this dried exudate contained 25.0 percent of lime and was rich in arsenic acid, 49.0 p. p. m. As this bleeding is confined almost exclusively to the marly soils, I infer that it is an effect of the lime rather than of the arsenic, though both are present.

I have tested a number of these marly soils and have not failed to find arsenic in them. I have, in years past, also met with instances of sick trees of which it was asserted that they had never been sprayed, but examination of the wood revealed the presence of arsenic. Such

*I am indebted to Dr. H. G. MacMillan for these and some other photographs that appear in this article.



Plate 5.—A near view of a Jonathan in the same orchard on good soil, same age as the younger Ganos.

trees always were smaller than they should have been and lacked thriftiness. This was the reason that my attention was called to them and that often in an attempt to prove to me that arsenic could not possibly be the cause of the trouble, but it was present and, as far as I can now recall, these cases were all on marly soils. So generally was this the case that in the bulletins previously referred to I insisted on the probability of lime poisoning, though I am aware that there are good orchards in limestone countries. While this marl is essentially calcic carbonate, it has little else in common with limestone, and is an entirely different article from the gray, blue and green marls of New Jersey.

It may be well to state explicitly that the arsenic here referred to as occurring in these marls has not been derived from the spray materials used in combating the codling moth. It is true that such material is added to the soil and certainly is playing an important part in many instances, but it is here intended to present another phase of the question, primarily the action of marl which we find to contain arsenic, but we have no means of distinguishing the individual action of the separate factors. There is but one channel open through which any endeavor to distinguish them from one another can be made, and that is to find some instances in which the lime is absent. Instances of this sort which are satisfactory in other respects are difficult to find.

A very large percentage of our lands planted to orchards are either alkaline or marly. The alkaline lands themselves are usually well supplied with lime as the so-called alkalis usually carry from 12 to 35 percent of calcic sulfate, besides, these soils carry varying quantities of calcic carbonate. Under these conditions it is as good as impossible to determine from field observations to what factors the thriftless condition of the orchard may be due, and to which one, if any, specific phase of the trouble it is to be attributed. In addition, troubles due to fungi or other causes may appear and render the field case very complicated. On the other hand, it is in the field only that experiments can be made extending over the periods of time involved and on the scale necessary to assure actual cultural conditions.

The trees shown in Plate 1, for instance, are about 17 years old, while those in Plate 3 are, I think, 16 years old. They were sprayed with arsenicals for grasshoppers when they were young and have been sprayed for codling moth since they came into bearing. The soil in which the trees illustrated in Plate 3 have grown is 2.5 feet deep before any segregations of marl appear, while that in which those of Plate 1 have grown is not more than 12 inches deep, which is succeeded by a marl so rich in calcic carbonate that it is white, even while moist. Both soils contained arsenic before they were set to apple trees; in so far, they are alike. The trees have probably received about the same amount of arsenical sprays and about the same irrigation.

COVER CROPS AND MANURES PARTIALLY MITIGATE TROUBLES

The question of starvation in such cases is so evident that I considered it a factor 25 years ago, and acting on this idea, advised the application of manure as a corrective for an orchard which was in a bad state; rosetting was very prevalent. In another case I advised plowing to permit aeration and the growing of cover crops to plow under and not for hay. These measures mitigated the trouble somewhat. It is a question how great an improvement one is to expect in an orchard which has reached its bearing age or is older and is in the condition of these orchards. Of course the owner hopes that you know just what to do to restore the orchard to health and vigor. The orchard shown in Plate 1 was heavily manured when young, but not of late years as far as I know. The soil, what there is of it, in this case, is good, but the marl is too near the surface.

ORCHARD SOILS VARY WIDELY

The requirements of an orchard soil have not been specified. I imagine that the range in chemical composition of soils in which the apple tree thrives is a wide one. A few of our Colorado soils in which the trees grow well are the following:

TABLE I.—SOME ORCHARD SOILS

	Soil 1 Percent	Soil 2 Percent	Soil 3 Percent	Soil 4 Percent	Soil 5 Percent
Sand	74.82	69.036	70.80	60.966	69.553
SiO_2	5.65	3.761	3.54	16.228	8.447
CO_2	7.04	6.431	2.47	1.730	3.689
Cl	0.89	0.180	0.18	trace	0.098
SO_3	0.81	0.191	0.07	0.247	0.257
P_2O_5	0.18	0.248	0.13	0.091	0.159
Al_2O_3	2.25	2.383	5.48	3.746	2.981
Fe_2O_3	3.13	2.760	3.74	3.697	3.375
Mu_3O_4	(?)	0.075	0.11	0.644	0.100
CaO	7.18	6.300	3.58	3.176	3.800
MgO	2.19	2.569	1.63	1.651	1.874
K_2O	0.69	0.727	0.53	1.240	0.810
M_2O	0.84	0.317	1.00	0.423	0.513
Ignition	4.44	(4.071)	7.19	6.482	3.770
	100.11	100.041	100.45	100.330	99.426
O=Cl	0.20	0.041	0.04		0.022
	99.91	100.000	100.41	100.330	99.404

The first, second and fourth of these soils are from the same section, the third is from another county. The orchards that grew on these soils would be classed as well grown and healthy ones. The orchard on soil 3 was really a peach orchard adjacent to an apple orchard, number 4. This apple orchard was the least thrifty of the four and the soil was not very deep. As far as the agricultural analyses go, they show the soils to be rather good ones. The total nitrogen in them was only moderate, not above 0.098 percent; in some of them as low as 0.055 percent.

The subsoil in the cases of 1, 2 and 5 was not marly, but the subsoil of number 4 was somewhat so and the trees in this orchard were not as large and thrifty as the others. Many of them died as years passed and large portions of the orchard have been removed, a little at a time. The failure was slow. It is also true that orchards 1, 2 and 5 perished, but suddenly and from a definitely known cause—nitre that developed in the soil. Plate 10 is a photograph of the orchard grown in soil 1. The upper figure shows the size and thriftiness of these trees, and even the dead trees in the lower figure show that they were large and vigorous at the time disaster overtook them. Orchards on soils 2 and 5 were equally thrifty and the soils showed no marl to a depth of 7 feet. Soils 1, 2 and 5 represent good orchard soils under ordinary conditions, while 3 and 4 represent a red-mesa soil underlaid by marl. The depth of this soil in the apple orchard varied but was less than in the peach orchard.

The question of starvation is really not answered but the soil is rich enough in all the elements considered as important to support the growth of the trees. The only feature that lessens the force of the fact that the soil is adequately supplied with plant food is its shallowness. It is nowhere shown in how shallow a soil apple trees will grow. I have made many sections of soil to study this and found but few roots deeper than 2½ feet, and have found them almost exclusively confined to the top 12 inches of the soil, and these were fairly good trees. Why the roots had not gone deeper was not evident, but was probably due to the shales and their decomposition products which occurred within 2½ feet of the surface, and in places nearer.

The marly soils and subsoils may be represented by the following analyses:

TABLE II.—ANALYSES OF MARLY SOILS, SUBSOILS AND MARL

	Soil 1 Percent	Subsoil 1 Percent	Soil 2 Percent	Subsoil 2 Percent	Marl Percent
Insoluble	48.589	55.683	73.964	50.775	24.098
SiO_2	17.071	2.866	6.412	8.842	8.269
CO_2	8.532	12.444	0.173	13.010	27.115
Cl	0.008	trace	none	trace	trace
SO_3	0.035	trace	0.017	trace	0.350
P_2O_5	0.036	trace	0.198	trace	trace
Al_2O_3	4.554	1.326	6.140	4.820)	
Fe_2O_3	4.890	3.428	4.580	3.600)	
					1.960
Mn_2O_4	0.179	0.260	none	trace	0.180
CaO	11.695	16.538	1.000	6.860	34.525
MgO	1.674	2.438	1.676	4.390	2.942
K_2O	0.589	0.360	0.175	0.208	
Na_2O	0.374	0.390	0.057	0.637	
Ignition	(1.776)	4.300	5.620	6.630	
Sum	100.002		100.022		
O=Cl	0.002		0.004		
Total	100.000	100.000	100..018	99.782	99.439



Lower half of trees in central orchard about 30 years old. The bark of these trees is yellow and the foliage scant. Rosette is present on some trees.

The soil and subsoil from the first pair are not from the same orchard, but the second pair and the marl are from the same orchard. The nitrogen in the first subsoil given was 0.06 percent.

STARVATION AS A POSSIBLE TROUBLE

The subsoils and the marl are very poor in phosphoric acid, and none of these analyses show a great abundance of potash. The feature of starvation deserves serious consideration and it seems to be emphasized by these analyses. Analysis 3 of Table II is of red-mesa soil and is well supplied with phosphoric acid. At the time this sample was taken the trees were nine years old and were in bad condition, small and without thrift. They showed rosetting to an unusual extent and the bark of both trunks and limbs was yellowish-red. Some of the trees were dead and others dying. The soil was shallow, less than a foot—my notes say about 9 inches.

One of these dying trees was dug up and the roots had not penetrated the subsoil, but spread out on top of it, which brought them very near to the surface. There may be a question whether this shallow soil was sufficient to supply the demands of the trees, even though it is fairly well supplied with the necessary food elements. The roots in this case seemed to be in good condition except they were externally black, a condition that I have found quite general in such cases, and the root system was meagre. There is no considerable quantity of manganese present in either the soil or subsoil to give rise to a deposit of black oxid of manganese on the roots, but some discolored roots from another locality were collected and the darkened bark tested for manganese by scraping off the outer portion and burning it. The ash was nearly white, and did not show the presence of manganese on being tested for this element. The darkening was not due to manganese. I have found this lack of root development in every case that I have examined where the soil was marly.

The deportment of these marly soils and subsoils toward water may play a part in this matter, but there is, apart from this, something radically wrong.

MARLY SUBSOILS MAY OR MAY NOT ABSORB WATER

The deportment toward water had in mind is that these marly subsoils may refuse to take up water, or may take it up very readily and become almost miry. I found an illustration of the former in an orchard representing the soil given in analysis 3, Table II. The water had been running for 24 hours. I turned it out of the furrow and made a cross-section. The water had not penetrated the soil and sides of the furrow for more than three quarters of an inch. In such case, only the surface soil, i. e., that above the subsoil, could be made wet and the trees might easily suffer for the want of water before the next irrigation. When it is too open, it drains easily and becomes dry. I recently examined a marl of this sort and found it very dry 30 inches below the surface, though this portion of the orchard had had a fair irrigation, as much as other portions of the orchard, but this was really

not sufficient. The trees shown in Plate 1 have to contend against such conditions. I have deemed it wise to point out these cultural features of the problem which may contribute to the difficulties, especially as they do not receive sufficient consideration by the owner or irrigator who often fails to appreciate the problem that confronts him.

NO DEFINITE CONCLUSION CAN BE DRAWN

While the analyses of marly soils and subsoils given justify misgivings as to their fertility being adequate to support a vigorous growth in an apple tree, no one acquainted with the problem as it presents itself in the field will be willing to accept this as a sufficient and satisfactory explanation, because there are too many instances of sick trees which cannot be attributed to a deficient fertility in the soil, though this, of itself, when actually the case, might be sufficient to explain some of the conditions found. But in these marly soils we find small, unhealthy, even dying trees, which have a root system which is not sufficient to grow strong, healthy trees, even when there is enough plant food present. The apple tree, especially, seems to suffer from the presence of these marls in the soil. Plate 9, lower figure, while not intended to illustrate the general condition of the orchard, serves this purpose very well. The trees were 18 or 20 years old when this picture was taken, and, while it is intended to show the cracked bark and profuse bleeding of the tree in the foreground, it shows the small size of the trees, though the orchard had been well kept and was then in fine condition. The trees in Plates 6, 7 and 8 are of the same age, now more than 30 years old, and set in the same kind of soil. This soil is shallow, perhaps 12 inches, but is not so sharply separated from the subsoil which simply increases in its content of lime but does not pass into a marl, as is the case in many instances. There is, however, only a very sparing development of roots in this subsoil.

There is, evidently, an antagonism between the apple tree and this soil, but it is not evident to which this is principally due—to the marl or to the arsenic that is present in it. The facts as presented seem almost to justify the assertion that is is due to this association of the lime and arsenic in the marl. The phosphoric acid supply is meagre, the arsenic, probably present as arsenic acid and being similar to the phosphoric acid, may be taken up in its stead; the former is beneficial and the latter prejudicial and adds its bad effects to the other difficulties that the tree has to encounter. This surface soil is, I think, fairly represented by the following analyses:

TABLE III.—ANALYSES OF A MARLY SOIL AND TWO SUBSOILS

	Soil Percent	Subsoil Percent	Subsoil Percent
Moisture		1.510	7.435
Insoluble	48.589	68.352	21.319
SiO_2	17.071	5.600	6.117
CO_2	8.532	4.579	17.055
Cl	0.008	0.139	trace
SO_3	0.035	0.033	10.650
P_2O_5	0.036	0.110	0.036
Al_2O_3	4.554	5.005	0.020
Fe_2O_3	4.890	3.840	2.270
Mn_3O_4	0.179	0.040	0.020
CaO	11.695	6.375	29.940
MgO	1.674	1.532	1.595
K_2O	0.589	0.506	0.673
Na_2O	0.374	0.249	0.069
Ignition	(1.274)	1.753	1.464
	100.000	99.623	100.627

The phosphoric acid in this soil is low, but whether or not it is too low to support a healthy development in an apple tree I do not know; it is below the conventional amount supposed to constitute the lower limit for good soils. The potash is sufficiently abundant and the total nitrogen is abundant, 0.386 percent.

On this land we have all of the features of sick trees. The orchard is now an old one for this section of the country; I would judge upwards of 30 years old. I have known it nearly 25 years and it was a bearing orchard when I first learned of it. Here we have small trees, as shown in Plate 6, with a yellowish-red bark with a small root development, and in the past, profuse bleeding as illustrated in Plate 10. Some trees in this orchard succumbed to irritant arsenical poisoning, possibly due to the liberal use of calcic arsenite, soda, lime and white arsenic, probably also of lime and Paris green in its early history. The wood of these trees, dead or living, yields, on examination, arsenic in liberal quantities. By using the term "wood," we mean to exclude the bark. The history of this orchard assures the presence of arsenic, lead and copper in the soil, whether or not as virgin soil or as marl it carried arsenic. It very probably did carry it. The dried juice, shown on the trees in Plate 9, was very rich in lime and arsenic. This fact alone shows that these constituents are in the juices of the trees and are not mechanically absorbed through the bark. These pictures were taken, as were the sample, before the trees had been sprayed that season.

It was conclusively shown in Bulletin 157, and in the article on the "Occurrence of Arsenic in Soils, Fruits, etc.," referred to at the beginning of this bulletin, that arsenic not only occurs in virgin soils but is taken up by various plants, and its appearance in fruits does not of itself prove that it has been derived directly from the spray material. It may have been supplied from the soil by the circulation of the solutions taken up by the roots. In this connection it becomes important to consider that arsenic, as well as lime, may be acquired from the soil, and



Plate 7. A nearer view of one of the trees shown in Plate 6.

how little of them may injure a plant. This we have not done except indirectly, but we have shown in former bulletins that the insoluble arsenical sprays applied to the trees are rendered soluble to a very perceptible extent by the salts that are abundantly present in all of our soils, and especially abundant in many of those that have been set to apple trees. We have also shown the presence of arsenic in both sprayed and unsprayed plants in such a number of instances that its presence in many plants cannot be questioned.

What the physiological effects of arsenic in such quantities as may be absorbed from the soil may be, is not known to me. I do not think that it has been demonstrated by anyone, but in larger quantities it is quickly fatal. The effects of lime, as far as I know, have not been studied except in a few cases of chlorosis that have been induced by this substance, but I do not think that their joint action has been considered at all. This question was forced on our attention some 17 years ago by this bleeding of trees and the composition of the dried exudate, which, in some cases, formed stalactitic masses several inches in length.

ASH COMPOSITION OF NORMAL AND DEAD TREES

We made an attempt to ascertain the composition of the ash of a normal apple tree, and of such as were dying from the joint effects of arsenic and lime. Two important questions arose at the time: How may you know whether you are dealing with a normal apple tree and how do you know that the condition of the trees complained of is due to the joint effects of arsenic and lime? I appealed to the literature pertaining to the former answer, but found nothing satisfactory, in fact, I found as good as nothing. In regard to the second, we could not separate them, as the arsenic and lime were associated in the exudate and occurred associated in the marl, whether the land had ever been sprayed or not. This was the case with all of the marls and even of virgin soils that I tested. (Bulletin 157, p. 40).

Concerning the ash constituents contained in plants, one can assume that their relative quantities will vary within certain limits according to the soil on which they grow, and that these limits may be pretty wide even in perfectly healthy plants. Different parts, too, may differ, so that one should not compare the ash of the trunk of one tree with that of small limbs of another. Such ashes differ somewhat when they represent parts of the same tree.

I sought to find out what differences these sick trees, grown on marly soils, would show in this respect when compared with a tree of the same variety grown under more favorable conditions in the same district but which did not show these signs of distress. The sick and dead trees used were grown on the soil of which we have given an analysis in Table III. One subsoil was from the same orchard. The tree chosen to represent a healthy one was grown on a sandy loam with a sandy subsoil within 3 or 4 miles of the former, so the climate was not materially different. The sick trees had the better cultivation.



Plate 8.—A nearer view of another tree in Plate 6.

In each case I separated the bark from the wood and found that the sick tree contained a higher percentage of ash in both the wood and the bark than the healthy tree. The wood of the sick tree carried 0.539, that of the healthy tree 0.389 percent; the bark of the sick tree carried 10.452 and that of the healthy tree 7.21 percent of ash. The analyses of these ashes, taken from Bulletin 157 are as follows:

TABLE IV.—ANALYSES OF APPLE-TREE ASHES

	Living Tree Sandy Loam		Living Tree Marly Soil		Dead Tree Marly Soil	
	Wood Percent	Bark Percent	Wood Percent	Bark Percent	Wood Percent	Bark Percent
SiO_2	0.837	0.944	0.807	0.774	0.604	0.552
CO_2	29.549	36.615	33.826	35.467	34.970	39.395
Cl	Trace	0.195	trace	trace	0.406	0.135
SO_3	1.884	0.554	1.821	0.449	1.474	0.396
P_2O_5	5.094	3.170	4.524	1.500	3.170	1.234
Fe_2O_3	0.105	0.212	0.199	0.184	0.130	0.182
Mn_3O_4	0.147	0.101	0.143	0.175	0.149	0.127
CaO	26.000	49.141	35.920	54.320	41.264	53.697
MgO	9.289	3.189	7.574	1.408	8.073	1.125
K_2O	26.621	5.264	14.298	5.200	4.999	1.750
Na_2O	0.474	0.615	0.888	0.523	4.761	1.407
	100,000	100,000	100.000	100.000	100.000	100.000

These ashes are very different, especially those representing the wood and bark of the dead tree. This tree had probably died during the preceding season and was still standing when the wood was taken.

The sulfuric acid is the same in the wood of the three trees, also in the bark but is less in the bark than in the wood ashes. The phosphoric acid is less in both the wood and bark of the trees on marly soil than in the wood and bark respectively of the trees grown on sandy loam. The iron and manganese are the same in all samples. The lime is higher in the bark than in the wood and very much higher in the sick and dead tree than in the healthy one; this is not true of the magnesia. The potash is much higher in the wood of the healthy tree than in the others; it is very low in the bark of the dead tree but is present in equal quantities in the other two. The inference, if any may be drawn from these results, is that the marly soil has greatly increased the lime and suppressed the potash, but was without effect on the iron and manganese.

The New York Station, Geneva, published *in 1891 analyses of the ash of young trees in which the lime is very high and the potash very low; 42 and 44 percent for lime and 5.7 and 5.4 percent for the potash. These data are much like ours for trees grown on marly soils. They obtained 5.9 and 4.9 percent for the phosphoric acid which is a little higher than we find in the healthy tree on sandy loam. As I know nothing about the New York soil, further comparisons would be ill-advised. It seems more probable that our condition is caused by the

*Report New York Experiment Station Geneva, 1891, p. 164.



Colo. Ag. Expt. Sta.

Plate 9.—To show bleeding deposits of dried juice and general condition of orchard.

joint action of the marl and arsenic rather than of the marl alone. It would also appear that our trees fail to obtain a sufficient supply of phosphoric acid, which I believe to be due more to an unhealthy condition than to lack of its supply.

This goes back to the question raised at least twice in previous paragraphs relative to the depth of good soil that will suffice to grow and sustain trees in good health. The very meagre root system developed by these trees would seem inadequate to supply even the trees that develop, and as this development is generally found in marly soils, it may be considered as indicating an antagonism toward the roots of the apple.

CONDITION NOT CONFINED TO COLORADO

The effects of this condition are not confined to apple trees, though with us this appears to be the most marked instance of them. Prof. J. J. Thornber, Director of the Arizona Experiment Station, Tucson, Arizona, kindly furnished me, some years ago, a sample of caliche, which was a rather firm calcic carbonate and is the equivalent of our marl, which is usually friable or even powdery. I desired the sample of Arizona caliche in order to examine it for arsenic to see if this element occurred in samples of marl outside of Colorado.

Professor Thornber described this occurrence as follows:

"The upper layer is usually quite pure and very hard, while the lower layers are softer and quite sandy. As we pass through the caliche stratum it gradually becomes softer and filled with sand, after which one usually comes into pure sand."

The sample that I received had a brownish-white color, was compact, somewhat stratified, and contained pebbles of quartz and igneous rocks. The hardness of this sample would present very great resistance to penetration by roots of ordinary plants. The arsenic was so abundant that in manipulating 100 grams of it I obtained a solution that gave, when brought into an active Marsh apparatus, a distinct mirror in less than one minute. The solution was too rich in arsenic for manipulation by this method. As it was, I recovered 130.3 p. p. m. calculated as arsenic acid.

Professor Thornber's description of the caliche stratum and the sample that he sent me agree in showing that the compactness of the upper portion is due to slow deposition or to cementing at a later period.

At the time Professor Thornber sent me this sample, he merely mentioned the fact that rose bushes would not live under this soil condition. He has recently given me more details of his observations and kindly permits me to use them. The rose bushes would not live, so he excavated a trench of considerable size and filled it with good soil and the whole difficulty was obviated. Professor Thornber has observed the deleterious effects of this caliche, or carbonate of lime, on a large number of plants. The experiment of Professor Thornber with the rose bushes is, perhaps, more satisfactory and direct proof of the part played by the caliche than any of my observations, and I am glad to be able to give this case.



Plate 10.—To show the vigor of trees grown in soil free from marl but which perished from other causes.

Our illustrations representing Gano trees that differ only one year in age, growing in the same orchard but under different soil conditions show the same facts; where the trees are sick, many of them having died, the marl, a very soft, even powdery one, is near the surface but where they are vigorous and healthy, even large for their age, there is no marl within 2½ feet of the surface. The aspect of the orchard is such that ordinary climatic questions are eliminated, but they are even more satisfactorily set aside in Prof. Thornber's experiment.

SUMMARY

The object had in view in writing this bulletin has been to offer some explanations for the conditions prevailing in many of our orchards.

We have attempted this as a contribution to our general knowledge because we believe that these facts apply to a very much larger section than our own.

That these conditions are serious is, I am sorry to say, evident to persons acquainted with the history of the past 25 years in some of our orchard sections.

There have been at least four factors that have been effective in bringing about these conditions. I have referred to them in the order that they have manifested themselves. The first was the acute irritant poisoning of the trees, owing to the corrosive action of the arsenic on the crowns of the trees. It was never plain that the alkalis present in our soils contributed to this phase of the trouble. They may have done so, but it was not evident that they did. This trouble was mitigated greatly by the use of lead arsenate instead of the older sprays. This trouble was serious enough but not comparable with the one that followed it.

The second factor that became active in producing the present condition in our orchards was recognized about 1909 when many trees were killed quickly and many orchards were affected. This cause was the development of injurious quantities of nitrates in the soil. This continues to the present time. The only way found to combat this is to grow cover crops and plow them under. The damage done by this cause has been very great.

The third factor is the necessity under which the orchardists have been of applying many heavy sprayings annually to their trees to combat their principal insect enemy, the codling moth. These arsenical sprays, of late years almost exclusively lead arsenate, must eventually find their way into the soil where they are gradually acted on by the sodic sulfate, sodic chlorid, and sodic carbonate, when present, which render the arsenic soluble and absorbable by the roots. Whether the lime salts present in these soils are active factors in these changes has not been made out. The fact is that the wood, leaves, and fruit of these trees contain arsenic, and the wood, and, so far as tested, the leaves, contain lead and copper. Under these conditions we fear that systemic poisoning is beginning to be a real danger.

We have not observed any instance of direct injury caused by "white alkali" alone.

A further factor is the marl that occurs in our soils, sometimes as a layer of loose calcic carbonate, occasionally quite compact, and it may be mixed with sulfate of lime. There are several questions that present themselves in this connection—two distinct ones at least. When this marl occurs within a few inches, 9 to 18 inches, of surface and the roots of the trees refuse to develop in it, the question arises whether this is due principally to an antagonism between the plants and the marl or due to the absence of sustaining foods; in other words, whether it is due to starvation or injury of the roots by the lime.

Trees grown on such soils are small, with reddish or yellowish-red bark, and lack thriftiness. They are recognized as sick trees, very similar to many trees that have been poisoned by arsenic. In fact, they have frequently been pointed out to me in refutation of the claim that similar trees were being killed by arsenic. The force of the argument lay in the fact that these trees had never been sprayed. Arsenic, however, was uniformly present in the wood of such trees. These marls contain arsenic, as do many of our virgin soils. Such cases present the question of poisoning by the joint action of lime and arsenic.

In regard to the question of simple starvation, I have no direct proof that this has actually been the case in any orchard, but its possibility, where the surface soil is less than a foot deep, must be admitted until it has been proved that trees can grow healthily in such shallow soils. At the present time I am not inclined to accept this as entering as an important factor in our case.

As we cannot recognize the separate effects of the lime and arsenic, and as these occur in the deposits formed on bleeding trees in large quantities, we assume that the action on the tree is a joint one.

Our ash analyses show that the marly soil has increased the lime greatly and suppressed the phosphoric acid and potash. This might be attributed to the lack of these constituents in the marly subsoil; on the other hand, the iron and manganese are not suppressed and in some ash analyses, published by the New York Geneva station, I find more lime given without any depression of the phosphoric acid, so that high lime in the ash is not incompatible with high or normal phosphoric acid. Persons familiar with these conditions are not inclined to accept the starvation theory as explaining many of the cases. There remains by far the greater part of them to be attributed to the poisonous action of the limy soils and marly subsoils.

Whatever may be the cause of these difficulties, one thing stands out clearly, to wit, that a shallow soil underlaid by marl, such as we have in this country, cannot be considered a fit soil for apples and it may be questioned whether it is an orchard soil in general.

GENERAL REMEDIAL SUGGESTIONS

The first step in combating the difficulties described in this bulletin is to avoid such soils. The second step is early and deep cultivation

with the application of fertilizers. Cover crops plowed under is about the only feasible fertilizer in this country. It is generally accepted that a cover crop is grown to be plowed under, but if alfalfa or red clover is used for this purpose, it is used for hay and not for manure and in the end only the stubble or a very small growth of green crop is actually added to the soil.

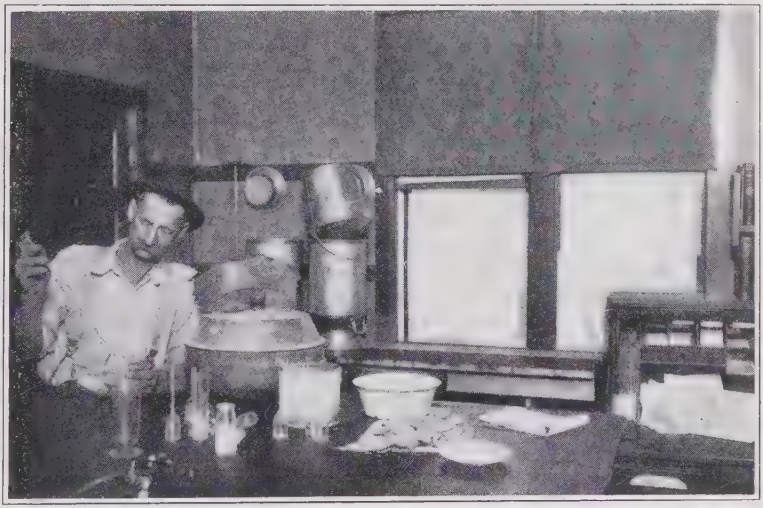
It is a good practice to grow cover crops and incorporate them in the soil of our orchards, old or young, as often as is feasible, both to obviate the lime trouble and to keep the nitrates in control. It is really about the only practical method that is open to us. It is certainly the cheapest and probably the most efficient.

Number 295 December, 1924

MAKE THE DAIRY PAY

TESTING AND HANDLING MILK AND CREAM

By FLOYD E. BALL,
Deputy State Dairy Commissioner



Test Each Cow and Get Rid of the "Boarders"

COLORADO EXPERIMENT STATION
Agricultural Division
Fort Collins

FOREWORD

The farm separator was the big factor in changing the dairy farmer's marketing system. In the early days of the dairy development in this country, we had the whole-milk creameries and the factory separator. The creameries, in an effort to expand their milk supply territory, established skimming stations in convenient locations as to hauling distance and reasonable shipping distance. After the farm separator made its appearance the skimming station was gradually replaced by the cream receiving station.

The cream receiving station has been a large factor in developing the dairy industry in sections of this State where the cow population and herds were small, the farms far apart and the amount of cream produced within a reasonable distance too limited to profitably operate a local creamery.

By means of the cream receiving station the dairy farmers are furnished a home market, the skimmilk is kept on the farm where it belongs for the feeding of calves, hogs and chickens, thus making the dairy industry more permanent.

The station system of buying cream is being practiced by nearly all creameries in Colorado. The purpose of this bulletin is to secure uniform and accurate methods of testing and bring information to the attention of the producer, station operator and dairy manufacturer, which will bring about a mutual understanding of each others' problems. Co-operation of the parties mentioned above will aid greatly in effecting changes of great economic importance to the dairy industry in Colorado.

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MAKE THE DAIRY PAY

By Floyd E. Ball, Deputy State Dairy Commissioner

In reviewing the past twenty-three years of the dairy industry in Colorado, we find that the industry has developed rapidly, when we consider the fact that the main industries in the early days were the ranging of sheep and cattle, and mining. Figures show that at the beginning of 1900 the total value of all dairy products manufactured in Colorado was $3,257,625.00, in 1913, $7,900,000, in 1922, $20,214,795.00 and in 1923, $23,348,256.00. During the year 1923, the total value of all dairy products passed the combined values of all precious metals, equalled the combined values of gold, silver, zinc, lead, coal and potatoes, equalled the combined values of wheat and potatoes, and passed the combined values of gold and sugar beets. This is a very good showing for the dairy industry when Colorado is known as a mining state and is credited as being the leading beet-sugar producing state in the Union.

FUTURE OF DAIRYING

When we compare Colorado with the dairy states in this country, we find that she is in her infancy as far as the dairy industry as a whole is concerned, but with our natural advantages, such as climate and feed conditions, Colorado can be made one of the leading dairy states in the Union. The prospects at this time for future dairy development are encouraging.

However, there are two things that we, as producers and manufacturers of dairy products, must keep in mind and practice. They are herd improvement and quality of production. The consuming public is rightfully demanding good quality in any product and when competition is keen, a good-quality product is the one that sells best. On the other hand, the dairy farmer who is milking high-producing cows is the one who is getting ahead and making money.

HERD IMPROVEMENT

Dairying, when properly conducted, is one of the most profitable lines of livestock farming; but as a rule the average dairy farmer neither knows nor suspects the amount of profit or loss from each cow in his herd, which is the keynote to success in the dairy business. It is not the amount of money taken in or handled, but the money that stays in the pocket that counts. Every cow must eat, whether she produces much or little and she can return no profit to the owner until she has first paid for her board. To advance permanently in dairying, herd improvement must go on.

Herd Records.—Successful business concerns have a system of keeping records of all transactions in order that they may

stop leaks in the business and be able to tell which department is making or losing money. The dairy farmer should do the same thing and dairy herd records such as breeding, feed and production records can be easily kept. Any farmer who does not have a fairly accurate record of feed, an accurate record of production and breeding dates of his cows, is making a serious mistake. The actual time required to make such records is negligible when value of such records is considered. The selection of a herd for improved production is based upon the individual performance of each cow in the herd.

Records Necessary.—Records should be simple and easily kept. On the average dairy farm only two forms are necessary, one form to be used in the barn for the original record and another form to transfer the totals from the original barn re-

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Feed 1 lb. grain for every 3 or 4 lbs. milk.	Feed 3 lbs. of ensilage for every 100 lbs. live weight.

COLORADO AGRICULTURAL COLLEGE
EXPERIMENT STATION
Fort Collins, Colorado

Daily Milk and Feed Record for Month of..192........

Owner of Herd..............................Post Office..............................State..............................

Name of Cow		Remarks
1	A.M. P.M.	
2	A.M. P.M.	
3	A.M. P.M.	
Etc.		

	Prices of dairy products
Total lbs. milk	
Test (% butterfat)	
Total lbs. butterfat	
Value Whole Milk	
Value Butterfat	
Value of Skimmilk	
Total value of products	

AVERAGE DAILY FEED RECORD

	Prices of feed
Pounds	
Pounds	
Pounds	
Pounds	
Pounds	
Total cost of feed	
Income above feed cost	
Date bred	
Date calved	

USE PUREBRED BULLS WITH INDIVIDUALITY AND FROM COWS OF KNOWN PRODUCTION

cords in order that a permanent yearly record may be kept for each cow.

The barn sheet and permanent record sheet are used by a number of dairy farmers in Colorado. The forms submitted are a combination of many forms that are in use by the U. S. Department of Agriculture and many agricultural colleges.

Barn Sheet.—The first form is commonly called the barn sheet which is usually tacked on the barn wall to the right of the milk scale. On this form you will note blank spaces at the top for the cows' names under which you will find spaces for the daily milk record, total milk for the month, butterfat test, total pounds of butterfat, date bred, name of sire, date calved, average daily feed and price of feed. The original sheet is 19¾ inch wide and 23¾ inch long.

Permanent Record.—In order to have a record that is permanent and one that can be referred to easily, it is well to have an individual sheet for each cow. The following will be found to be very satisfactory:

Year..... 19.....

COLORADO AGRICULTURAL COLLEGE
EXPERIMENT STATION
Fort Collins, Colorado

Owner's name ..... Address .....

Name of cow ..... Age ..... Breed ..... Weight ..... Fresh .....

Date bred ..... Sire ..... Dam .....

Date calved ..... Date dry ..... Date sold ..... Price .....

Month	Month's Milk	Percent B.F.	Lbs. B. F.	Price of Product			Value product	Monthly feed Consumption								Cost pasture	Cost of roughage	Cost grain	Total cost of feed	Value of product over feed cost	Value of product below feed cost
				Skimmilk	Cream B.F.	Wholemilk															
Totals																					

Remarks: .....

HOW TO GET HERD IMPROVEMENT

In order to secure herd improvement, we must intelligently practice proper breeding, feeding and weeding. These three factors are fundamental and are practical, sound, business methods, which can be applied to all dairy herds if the owners expect to be successful in dairying and in building up the dairy industry to a higher plane.

Permanency of the dairy industry will not be measured by the total number of cows milked but will be measured by the number of cows milked that are returning a reasonable profit above cost of feed.

BREEDING

Dairy animals are bred, fed and developed for the express purpose of producing milk. The efficiency of the individual cow depends upon whether her ancestry has been intelligently selecetd and bred for butterfat production. Since like tends to beget like in individuality as well as in production, it is advisable to use only pure-bred bulls whose ancestors for at least five generations have been real performers as milk producers.

We can increase the production to a limited extent with the present herd by employing better bethods of care and feeding, but for lasting results the dairy farmer must plan for the future herd and aim for each succeeding generation to be better and more economical producers than the last. This can be accomplished by knowing the individual performance of each cow in the herd and then intelligently selecting and breeding accordingly.

Pure-bred Bulls.—It has been demonstrated repeatedly that the cheapest and easiest way to improve the herd is by using a good pure-bred bull. To give an idea of the amount of increased production to expect by using good purebred bulls, results of an experiment at the Iowa Agricultural College are presented. The men in charge purchased a number of scrub cows and conducted an experiment to determine the influence of purebred sires and of feed and enviornment on milk production. Purebred bulls of the Holstein, Guernsey and Jersey breeds were used on the scrub cows. Taking the three breeds as a group, the daughters of the scrub cows showed an average increase of 39 percent in milk and 25 percent in butterfat production. The second generation of grades of the three breeds taken as a group, showed an increase of 130 percent in milk and 109 percent buttrfat production. Such an increase gives an idea of what may be expected in increased production by using a good purebred bull on your cows. This showing certainly is a great tribute to a purebred sire.

FEEDING

Feeding, care and management go hand in hand, and in

order to secure maximum results in the production of milk, these factors must be given careful attention. Space will not permit going into detail regarding the importance of proper feeding and the influence of the three factors mentioned. However, the results secured by placing a herd under the proper environment and the benefits of fall freshening will be considered.

Environment.—Referring to the Iowa experiment again, the cows that were four years old when brought to the experiment station produced on the average of 3,084.6 pounds of milk and 149.2 pounds of butterfat. When given good feed and care, they steadily increased in production until at seven years of age, they were producing 4,907.7 pounds of milk and 229.9 pounds of butterfat, or 59 percent more milk and 54 percent more butterfat than they did during the first year at the station.

An increase of only 10 percent in milk and 8 percent in butterfat yield was expected as the result of maturity of the animals, and consequently the greater part of the increase obtained must be attributed to feed and care or enviornment. After deducting the natural increase, we still have an increase of 49 percent milk and 46 percent in butterfat, which is no small increase and shows the importance of feed and care or environment.

Fall Freshening.—The United States Department of Agriculture, after studying many thousands of individual cow-records, found the interesting fact that when cows freshen in the fall, particularly during the months of October, November and December, they produce 4 percent more milk and butterfat than if allowed to freshen in the summer months. Also, the price of butterfat is usually higher during the fall and winter months.

WEEDING

Since there is a great variation in the production of individuals of the same breed, it is necessary to keep records on each cow to discover and dispose of the unprofitable or "boarder" cows. It does not pay to keep "boarders". They reduce the profits, increase the cost of milk production and take all the pleasure out of dairy work. We must be careful in the weeding-out process and be sure not to dispose of a valuable animal. Do not dispose of an animal on one or two tests, but get a year's record on all animals before you sell, as it is the amount of butterfat produced in a year that tells the story.

The following table has been compiled by the United States Department of Agriculture from records from cow testing associations all over the country, and shows in a very comprehensive manner the relation existing between butterfat production and return above feed cost in dollars and cents:

RELATION BETWEEN BUTTERFAT PRODUCTION AND RETURN ABOVE FEED COST

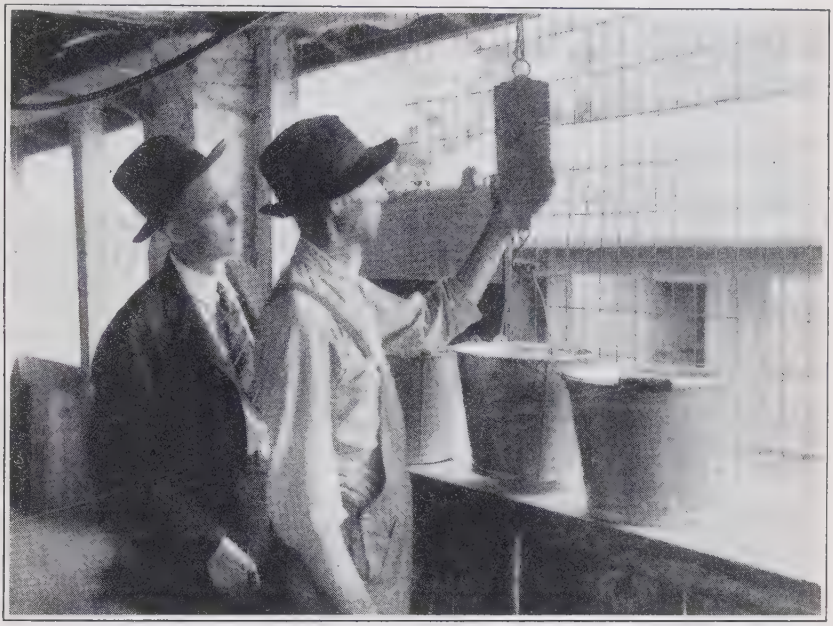
Group	Average pounds of butterfat produced in one year	Average income above feed cost for one year
1	24	$ 30.00 (loss)
2	50	19.00 (loss)
3	100	8.00
4	150	25.00
5	200	40.00
6	250	55.00
7	300	70.00
8	350	85.00
9	400	99.00
10	450	115.00
11	500	126.00
12	550	136.00
13	600	158.00

A glance at this table reveals that the cow giving 600 pounds of butterfat returns $158.00 annually, above her feed cost, while the cow producing 100 pounds makes a return of only $8.00. With six times the production the return is seen to be nearly twenty times as great, which conclusively shows the absolute necessity of weeding out the low producers and replacing them with more profitable individuals.

Cow-Testing Associations.—In districts where the herds and cow populations are large, the work mentioned above is usually carried on through cow-testing associations. In these organizetions a trained tester is employed, who spends one day every month with each of the members in the association. Arriving on the farm, usually in the afternoon, he weighs and samples the milk from each cow at milking time. He also weighs the concentrates and roughages given to each cow in the herd. The following morning this is repeated, after which the samples of milk are tested for butterfat. From this day's record he computes the milk and fat production and cost of feed for each cow for the current month. Naturally such records are not as exact as if every milking were weighed but the results are within 2 percent of the actual production of the cow. Considering the low cost of cow-testing-association work ($3.00 to $3.50 per cow per year), and the fact that these records have been shown to be within 2 percent of actual production, there is no cheaper way of keeping complete records on the herd than by this means, in places where there are sufficient cows to form such an organization. It would cost the average dairyman more in time, effort, supplies, etc., to do this work himself than to pay the $3.00 to $3.50 per year and have it done for him, receiving the additional advantages that go with cow-testing-association work as carried on at the present time under the supervision of the State Dairy Commissioner with the aid of the United States Department of Agriculture.

Individual Testing.—The weighing and testing of the milk from each cow is strongly recommended to determine her value

but if the work is not properly done the results are of no value and may give discredit where credit belongs.



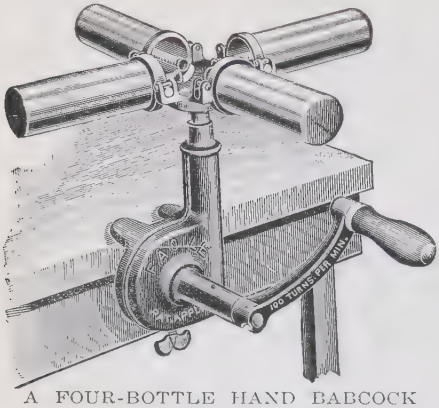
INDIVIDUAL RECORDS ARE NECESSARY TO ELIMINATE BOARDERS FROM THE HERD. WEIGH THE MILK FROM EACH COW AND RECORD IT.
(Courtesy U.S.D.A.)

In order that the results may not be misleading, all the milk from each cow must be carefully weighed and, to arrive at a true test, a representative sample must be taken. Just as soon as the cow is milked, weigh the milk, record weight, then pour the milk from one pail to another at least three times and dip the sample out at once. Keep the sample in a tightly covered jar or bottle until tested. Do not allow the sample to sour before testing.

A single test of this kind does not give much information regarding the cow's value but if carried on during the entire lactation period, that is weighing and sampling at least one day each month for the year, one will have a good idea of what the cow is worth. Do not condemn a cow on one test but give her a chance to perform for a year with proper feed and care, then if she does not return a reasonable profit over feed cost, send her to the butcher.

Producer is Loser.—If the factors mentioned above were practiced intellingently in Colorado on our present cow population, the increased production secured would amount to 31,119,-

569 pounds of butter or enough butter to feed 1,944,973 people at the present rate of butter consumption.



A FOUR-BOTTLE HAND BABCOCK TESTER.

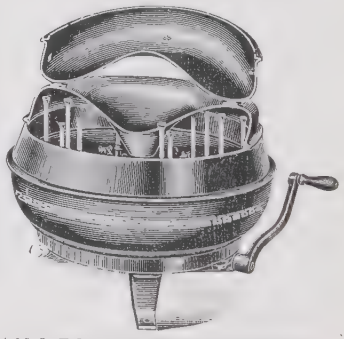
No doubt such increases bring the thought of over-production to mind. This is not of immediate concern and should not worry us because all the dairy farmers will not put these important factors to work at the same time and it is impossible to get immediate results. It will take time to secure the increased production mentioned and it will be brought about so gradually that increased consumption and the increase in population will absorb it. Should a temporary over-production be produced it will not vitally affect the dairy farmer who can raise his own feed and is milking paying cows. Also remember that the same production can be secured economically by milking fewer but better cows.

EQUIPMENT NECESSARY FOR HERD TESTING

The size of the testing outfit depends upon the size of the herd but for a small herd, the equipment listed below will be satisfactory:

One automatic scale (30 lb. capacity)	$ 5.50
One 4-bottle Babcock tester with necessary glassware equipment for milk	7.50
One dairy thermometer	1.25
Commercial sulphuric acid (1 quart)	.25
Total cost	$14.50

An 8-bottle covered machine with glassware complete will cost about $18.00. When many tests are to be run at one time, it is a saving of time to have a larger machine. It is advisable not to purchase more than one-half gallon of sulphuric acid at one time because the acid weakens with age.



AN 8-BOTTLE BABCOCK HAND TESTER.

Cream-test scales will be found to be expensive, the cost ranging from $10.00 to $20.00 for the one-battle size. Cream bottles will be needed for making cream tests which will cost about 25 cents apiece.

Remember accurate cream tests cannot be made without scales.

Dairy Information.—Any person desiring information pertaing to bull associations, cow-testing associations, feeding, pastures, or other matters pertaining to the dairy industry should address their inquiries to the State Dairy Commissioner, or Animal Husbandry Department at the Agricultural College, Fort Collins, Colorado.

PREPARATION OF MILK AND CREAM SAMPLES FOR MAILING

The State Dairy Commission will be very glad to test samples of milk and cream that reach the office in good condition. Samples arriving in a leaky, unsatisfactory condition will not be tested, because the result would not be accurate and would be misleading, but the sender will be notified of the probable cause of his trouble.

The following suggestions will serve as an outline to be followed:

1. Secure a representative sample by pouring milk or cream from one can to another at least three times. Sample must be smooth, free from streaks and lumps.
2. Fill a clean sample bottle. The bottle or jar should have a capacity of from two to four ounces. If the sample is not to be tested for adulterations or preservatives and is likely to be more than twenty-four hours in transit, add two or three drops of formaldehyde to prevent souring.
3. Seal the sample air tight. Test by inverting for an hour on white paper to see if the cover leaks.
4. Wipe the sample jar clean and dry, and pack well with plenty of soft, white paper in a small wooden or strong pasteboard box. Send by parcel post.
5. At the same time the shipment is made, send a letter stating what tests are desired. Give the name and address of the person taking the sample, of the person whose milk or cream was sampled, and of the person to whom analysis is to be sent.

QUALITY PRODUCTION

The principle of paying according to quality is as fundamental to good business in buying milk and cream as it is in buying other farm commodities. Everyone will agree that the principle is correct but a practical method of buying on a quality basis must be developed before it can be satisfactorily carried out. However, the producer and manufacturer should keep quality uppermost in their minds because the consuming public is becoming more and more appreciative of the value of wholesome food products of good quality, and is rightfully demanding a better quality of dairy products. Butter is sold largely on the quality basis, and it is logical, therefore, to buy cream on the same

basis. If all the butter produced in Colorado had scored 93 and brought a 93-score price, the returns would have been $968,200.00 greater for the year 1922.

ESSENTIAL FACTORS IN PRODUCING CLEAN MILK

Clean milk is milk of good flavor from healthy cows, free from dirt and containing only a small number of bacteria, none of which are harmful. The chief requisites in production of clean milk are:

Healthy Cows and Attendants.—Raw milk from cows afflicted with tuberculosis, or udder diseases, is unsafe for consumption. No slimy, ropy, or watery milk, or milk which is abnormal in any respect, or which comes from an animal that appears sick or out of condition, should be sold for human consumption. Naturally the attendants of the cows must be in a healthy condition and must not associate with persons suffering from infectious diseases.

Clean Cows and Attendants.—Under farm conditions, cows accumulate filth and manure on their bodies and if their flanks, udders and teats are not cleaned before milking, there is a good chance that some of these materials will fall into the milk pail during the process of milking and naturally pollute the milk with their respective odors and certain species of bacteria. The milkers should milk with clean, dry hands and protect the milk from contamination with dust, dirt and other impurities.

Clean Stables.—Whenever possible, the stable should be on high ground with good natural drainage. The barnyard should be kept dry and free from manure to avoid any unnecessary contamination. The stable should be kept clean, well lighted and well ventilated, to eliminate strong animal and manure odors. A separate building or milk house for handling the milk and dairy utensils is necessary.

Proper Feed and Water.—Certain moldy or decayed feeds, wild onions, etc., impart objectionable flavors to milk and cream. The danger from these feed flavors may be greatly minimized by feeding such feeds, four to six hours before milking. In case of wild onions and other pasture feeds or weeds, the cows should be removed from such pasture from four to six hours before milking. Plenty of clean, pure water is required for the herd and for the washing of the milk pails and other dairy utensils.

Small-Top Milk Pails.—Under bad conditions, considerable amount of dirt may fall from the cow into the milk pail. Thus it is advisable to use small-top or hooked milk pails.

Clean Utensils.—The utensils must be clean and as sterile as possible. All dairy utensils should first be rinsed with cold or luke-warm water, washed thoroughly in hot water containing some washing powder and then scalded with boiling hot water, or steam if available.

Necessary to Cool Milk Promptly.—Milk should be removed from the stable to the milk house as soon as drawn from each cow and cooled immediately to 50 degrees F. or lower and kept cool until delivered. Producers are losing thousands of dollars annually, due to the fact that the milk is not cooled promptly and efficiently.

ESSENTIAL FACTORS IN PRODUCING GOOD CREAM

All of the essential factors mentioned in producing clean milk, up to the cooling process, must be considered as essential factors in producing good clean cream. Additional factors to be considered are:

Location of Cream Separator.—The cream separator should be located in a separate building or milk house. The milk should be separated as soon as possible after milking, for it is then warm and in good condition to secure clean separation. The temperature of the milk has a direct effect on the percentage of fat in the cream and the skimmilk. The best practical temperature at which to separate the milk on the farm is about 90 degrees F.

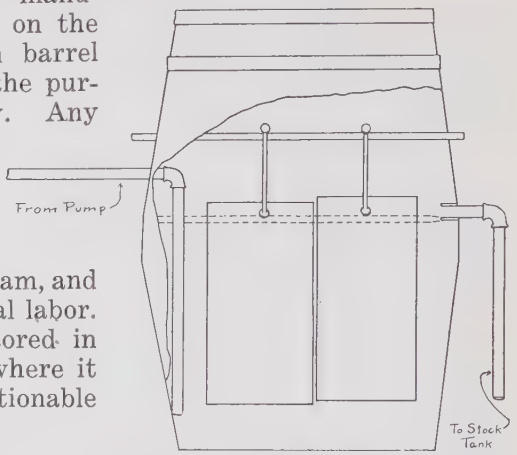
Cleanliness of Separator.—The cream separator collects many of the impurities contained in milk. The impurities are found in the slime deposits and unless the separator is washed thoroughly and freed from all these impurities and small amounts of milk of the previous separation, the separator bowl becomes a seat of contamination and the source of unclean, unwholesome and filthy cream, and bad effects of which cannot be overcome. It is impossible to make good butter from poor cream.

How to Wash the Separator.—After each separation, flush out the bowl thoroughly with water until the discharge from the skimmilk spout is clear. Then take the bowl apart and wash bowl, spouts, supply tank and buckets with a brush in moderately warm water containing some washing powder. Then rinse the parts in scalding hot water and steam them, if steam is available. Allow the parts to drain in a clean place, well protected from dust and flies.

Cool Cream Promptly.—Immediately after separation, place the cream in a cooling tank filled with cold water and keep it there until it leaves the farm. It is advisable to stir the cream twice daily to keep it smooth and free from lumps. Never mix warm cream with cold cream. It is advisable to keep all skimmings separate until day of delivery. If this is not possible you should at least use two cans, one for the fresh, warm cream and the other for the cold cream of previous separations. Deliver the cream as often as possible.

How to Cool Cream.—The only practical way to cool cream

on the average farm is to set the cream in a suitable tank filled with cold water. Many manufactured tanks are now on the market, but a common barrel may be made to serve the purpose very satisfactorily. Any tank through which fresh water passes to the stock tank will prove very helpful in assisting cream producers to deliver good cream, and with very little additional labor. Cream should not be stored in a cellar or other place where it is liable to absorb objectionable odor.



A BARREL ARRANGEMENT THAT MAKES A SUITABLE COOLING TANK

WHY CREAM TESTS VARY

The question is often raised by producers selling cream to creameries, why it is that their tests vary from time to time. A slight variation in the test will change the producer's proceeds quite materially and it is reasonable to expect him to watch the cream tests very closely as the test received determines the amount of money he will receive for his product. Variation in tests are due to a great many uncontrollable causes and frequently the cream buyer is unjustly accused of misreading tests.

Everyone familiar with the farm separator must acknowledge that it is one of the most highly perfected pieces of farm machinery in use. We expect it to do perfect work and it does, but it is expecting too much from even such a perfect machine to think that the same tests will result week after week and season after season, when there are so many variable and uncontrollable conditions entering in which will cause differences in richness of cream.

Aside from wear or mechanical adjustment and abuse by improper usage, the following factors will cause variations in tests.

Temperature of the Milk.—Separate the milk as soon after milking as possible, for it is then warm and in good condition to secure a clean separation. No separator will skim cold milk as well as warm milk. The best practical temperature at which to separate the milk on the farm is 90 degrees F. In winter it is advisable to warm the separator by running hot water through it, otherwise there will be a wide variation in the cream test and also loss of fat in the skimmilk.

Richness of Milk.—The richer the milk, the richer will be the

cream. Any condition that affects the richness of the milk will also influence the richness and the test of the cream. Refer to page 27 for factors affecting the fat content of milk.

Cream Screw.—The richness of the cream obtained from any farm separator is mainly determined and regulated by the cream screw. If the cream screw is turned so as to move the opening nearer the center, it will deliver richer cream. The cream screw should be set so that it will produce cream testing about 35 or 40 percent

Rate of Inflow.—If more milk is run into the machine than the capacity of the machine calls for, there is excessive loss of fat in the skimmilk. If the machine is underfied the test will be increased.

Speed of Machine.—The separator should be run at a uniform and proper speed as recommeded by the manufacturer.

Flushing the Bowl.—The amount of skimmilk or warm water that is used to flush the bowl and allowed to run into the cream can, will also affect the test of the cream. Experimental data shows that cream tests may be lowered from 1 to 10 percent according to the amount of milk or water used for flushing.

Unclean Separator.—The separator bowl should be cleaned thoroughly each time it is used. If this is not done properly the outlets for the skimmilk and cream may become clogged. This will cause inefficient skimming and is likely to cause variation in the test of the cream, and dirty separators will seriously affect the quality of cream.

The above conditions are likely to vary from time to time to a greater or less degree; therefore, a cream producer might expect to have a variation in his cream test.

DOES SOUR CREAM TEST MORE THAN SWEET?

Many have been led to believe that by holding their cream until it is real sour, they will get a higher test. This would be true under one condition, that is, if a can of cream were allowed to stand for a long time at a high temperature there would be enough moisture evaporate to increase slightly the percentage of fat, but this would be very slight, and in that length of time the cream would no longer be fit for human food. Still this would not bring a higher price, as the extra percentage of fat would only make up for the loss in weight from the moisture which evaporated. To illustrate: If there were 80 pounds of sweet cream, testing 30 percent fat, in this amount there would be just 24 pounds butterfat. Allow the cream to stand until 5 pounds of moisture has evaporated. This would then leave 75 pounds of cream, testing 32 percent. We would still have 24 pounds butterfat, but needless to say, the butter made from this 75 pounds of so-called cream would not be fit for human consumption.

TESTING AND HANDLING MILK AND CREAM

MILK TESTING

Sampling.—The sampling of milk is the most important operation in determining the butterfat content. Unless the sample is representative of the milk from which it is taken, the result of the test cannot be correct no matter how skillfully the work may be carried out. Before taking a sample for testing, the milk should be thoroughly mixed, either by pouring from one vessel to another at least three times, or by stirring it well with an ordinary stirring rod. Pouring from one vessel to another is considered the best method for mixing whole milk. Frozen or partly frozen milk should never be sampled for testing, since a sample of such milk will not be representative unless it is warmed gradually to a temperature of 70 degrees F.

Composite Samples.—The law provides: "In sampling milk from which composite tests are to be made, to determine the percent of butterfat contained therein, no such sample or sampling shall be lawful unless a sample be taken from each weighing and the quantity thus used shall be proportional to the total weight of milk sampled."

The sampling should be done the same as for taking sample for other tests, with the exception that the composite sample must be proportional to the quantity of milk from which it is taken.

Correct composite samples may be obtained by the use of the McKay Sampler.



A MILK SAMPLE BOTTLE.

Care of Milk Samples.—Samples of milk should be placed in air-tight receiving bottles, in order to prevent any evaporation. Should evaporation take place, the percent of fat increases, causing inaccurate returns. Tight sealing prevents evaporation.

Milk samples should not be permitted to sour before testing, as souring causes flakes or lumps of curd to form, which requires extra care in dissolving before testing. Souring may be prevented by keeping in a cool place or by use of some preservative, as formaldehyde or corrosive sublimate. If formaldehyde is used, use one part of formaldehyde to 1000 parts of milk. A tablet of corrosive sublimate will preserve 1 pint of milk for more than a week. When preservatives are added, the sample should be shaken to insure thorough mix-

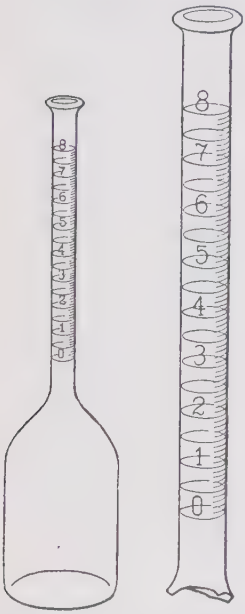
ing. After each addition of milk to the bottle, shake again, giving it a rotary motion until the contents are thoroughly mixed.

METHOD OF MAKING TESTS

Preparation of Sample for the Test.—Before testing, the samples in good condition should be brought to a temperature from 65 degrees to 75 degrees F. by placing in a waterbath. The contents of each bottle should be mixed thoroughly before pipetting into the test bottle.

The mixing of the sample is best accomplished by shaking the sample bottle and pouring the contents from one bottle to another several times.

Samples in which the fat has separated from the milk in the form of flakes or lumps should be gradually heated to a temperature of at least 100 degrees F., or until all lumps of butterfat have disappeared; the sample should be thoroughly shaken and gradually cooled. Be sure to shake continuously during the process of cooling. After the proper temperature has been reached be sure to pipette samples into the test bottle at once.



Type of Babcock milk-test bottle conforming to the requirements of the State Dairy Commissioner, showing graduations.

Milk Test Bottle.—An 8 per cent, 18-gram, so-called 6-inch milk test bottle is approved by the Dairy Commissioner. The total percent graduation shall be 8. The graduations shall represent whole percent, five-tenths percent, and tenths percent. The neck shall be cylindrical for at least 9 mm. below the lowest and above the highest graduation mark. The top of the neck shall be flared to a diameter of not less than 10 mm.

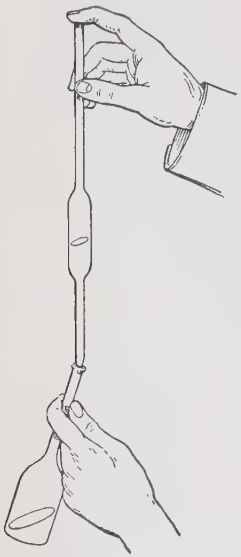


A 17.6 cc. milk pipette.

Measuring the Milk into Test Bottle.—Use a standard 17.6 cc. milk pipette and a standard 8 percent milk test bottle. Place the lower end of the pipette well down in the properly prepared sample and draw the milk into the pipette until it reaches a point in the pipette a short distance above mark around the upper stem. Then the forefinger is quickly placed over the upper end before the milk runs down below the mark. The pipette is then held vertically, with the mark around the stem on a level with

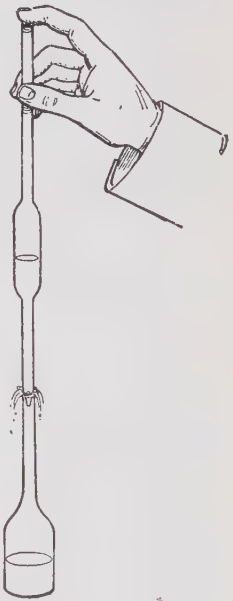
the eye, then gently relaxing the pressure of the finger on the end of the pipette, air is admitted and the milk is allowd to flow slowly out until the top of the milk column just reaches the mark around the stem of the pipette.

Transferring Sample of Milk to Test Bottle.—Incline the test bottle at an angle and place the lower point of the pipette within the neck and against the side of the test bottle. By raising the finger the milk is allowed to flow slowly down the inside of the neck of the bottle, thus allowing an exit for air in the bottle. This is not necessary when you have the long, narrow-nosed pipette which fits inside the neck of the bottle and the end of the pipette extends down into the bulb of the bottle. Blow the last drop of milk out of the pipette before removing it from the bottle.



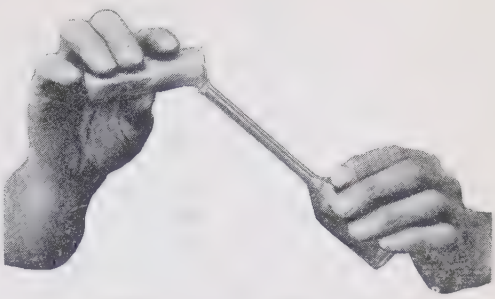
RIGHT WAY OF ADDING MILK TO THE TEST BOTTLE.

Not a drop of the milk should be allowed to spill outside the bottle in transferring from the pipette. In transferring milk, the pipette must never be held vertically in a line with the neck of the test bottle, as the narrow neck may easily choke up with milk and run over the top. Mark each bottle with a number corresponding with the name or number of the respective patron on the test sheet. All the tests should be made in duplicate so that one test will serve as a check on the other for accurate work.



THE WRONG WAY OF ADDING MILK TO THE TEST BOTTLE.

Add Acid—The milk and acid should be the same temperature, between 65 and 75 degrees F. Add 17.5 cc. of Commercial sulphuric acid, specific gravity being 1.823 to 1.385, acidity of 90.6 percent to 91.0 percent, to the test bottle. Hold the test bottle at an angle, carefully pouring acid down the side of the test bottle and do not let it drop through the body of the milk, the bottle being turned slowly at the same time so that any milk adhering to the neck will be washed down. By observing this precaution, charring of the milk and also spilling of the acid is avoided.

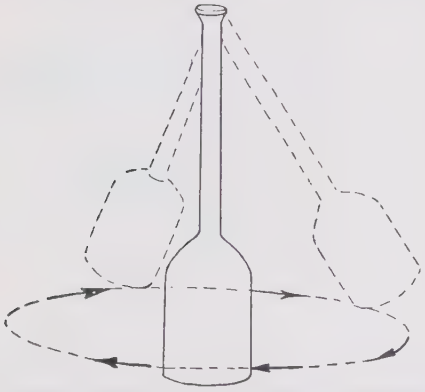


METHOD OF ADDING ACID

If the acid has been properly added there will be two distinct layers of acid and milk in the test bottle without much of a dark layer between them.

Sulphuric acid is an extremely corrosive liquid, which attacks the skin, the clothing, wood, and most of the common metals. Should the acid be spilled on the clothing, it should be immediately washed off with plenty of water, and ammonia water applied; this in turn must also be washed off. For these reasons acid should never be left any place where children have access to it.

Mixing Milk and Acid.—The mixing of the two is done best by giving the bottle a rotary shaking motion, being careful not to allow any casein to get into the neck of the bottle. Such mixing should be continued until the whole mass becomes liquid and free from solid particles of casein, and the color of the liquid appears uniform. Then the bottle should be allowed to stand for about three minutes, and given another gentle rotary motion before placing it in the tester or centrifuge.



MIXING THE ACID AND MILK IN THE TEST BOTTLE.

First Whirling.—The test bottles containing the mixture of milk and acid, after being properly mixed as stated above, are now placed in the tester or centrifuge and arranged in pairs at opposite sides of the center so that they will be in balance when rotating. Whirl the bottles at the proper speed of the machine for five minutes. If the test bottles containing the mixture of milk and acid are held over and allowed to become cool, they should be heated to at least 170 degrees by setting in a hot water bath before whirling or between whirlings. Some testers are equipped with heaters to be used during cold weather.

Speed of Tester or Centrifuge.—The proper speed of testers with wheels of different diameters has been calculated as follows:

Diameter of wheel in inches	Revolutions of wheel per minute
10	1,074
12	980
14	909
16	848
18	800
20	759
22	724
24	693

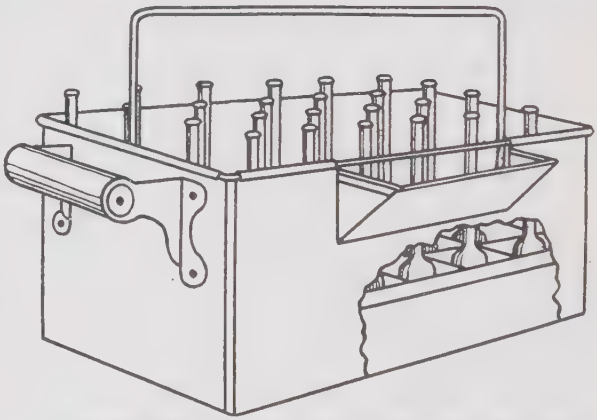
Adding the Water—The tester is then stopped and hot soft water at a temperature of at least 170 degrees F. (preferably near that of boiling water, 212 degrees F.) is added until the bowl of the bottle is filled up to where the neck of the bottle begins.

Second Whirling—After the water is added the bottles are whirled for two minutes.

Add Water the Second Time—After the bottles have whirled two minutes, enough hot soft water of the same temperature as in the first case is added until the butterfat column floats well within the graduated scale.

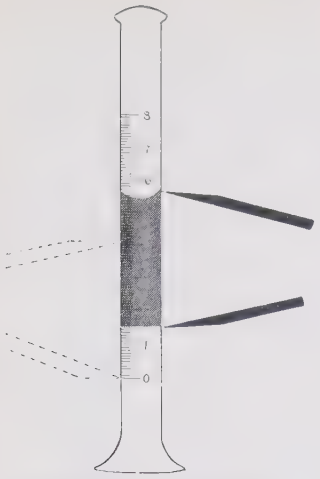
Third Whirling—After the second addition of hot water, whirl the bottles for one minute. When whirling the bottles remember that the five, two, and one-minute periods of whirling should not include the time required for starting and stopping but actual time of whirling at proper speed.

Place Bottles in Waterbath.—After the third whirling, remove the bottles from the machine and place them in hot waterbath in which the water is maintained at a temperature of 130 degrees F. and let stand for at least 5 minutes. The water in the waterbath should surround all the butterfat in the neck of the bottles. This is done in order that the butterfat may be brought to that temperature at which we secure the proper expansion of the butterfat globules and at which the bottles are standardized. Fat, like other substances, expands and contracts with heat and cold, so to get a correct reading, the hot waterbath is used.



A WATERBATH WHICH IS USED TO CONTROL READING TEMPERATURES.

How to Read Milk Tests.—If the test has been properly conducted, the fat column will be clear and of a golden, yellow



METHOD OF READING MILK TESTS.

color. Milk test should be read at a temperature of 130 degrees F. This temperature will insure sharply defined upper and lower limits of the fat column. In reading the tests, hold the bottles vertically and on a level with the eye. Then measure the test by using a pair of sharp-pointed dividers, placing one point of the dividers at the extreme bottom of the fat column or lower meniscus and the other point at the extreme top of the upper curved surface of the fat column or upper meniscus. Then lower the dividers until the lower point rests on zero graduation of the test bottle, the graduation where the top leg rests, if noted and read, will be the percent of fat. Care must be taken to hold dividers rigid while lowering. Place the reading secured on the receiving sheet in its proper place. Always read each test twice to make sure no mistakes have been made. If your check test does not agree with the first reading something is wrong and test should be re-run. In reading milk tests do not use glymol or any other reading oil.

DIFFERENT STEPS IN TESTING MILK BRIEFLY STATED

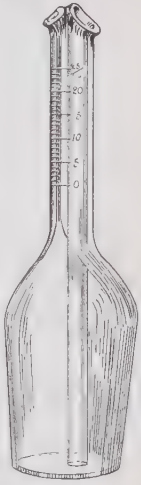
1. Secure a representative sample.
2. Mix each sample thoroughly at a temperature between 65 and 75 degrees F.
3. Fill immediately a 17.6 cc. pipette to mark around stem of pipette.
4. Transfer milk from pipette to test bottle.
5. Add about 17.5 cc. of acid to test bottle.
6. a. Mix milk and acid thoroughly by rotary motion.
   b. Let stand for at least 3 minutes.
   c. Mix again before placing in machine.
7. Place bottles in machine and whirl at proper speed for five minutes.
8. Stop machine, add enough hot soft water of a temperature at least 170 degrees F. to fill bulb of bottle.
9. Whirl as before for two minutes.
10. Stop machine, add enough hot soft water of a temperature at least 170 degrees F. so the butterfat column will float within the graduated scale.
11. Whirl as before for one minute.
12. Stop machine, remove bottles and place them in a hot

waterbath maintained at a temperature of 130 degrees F. for at least five minutes before reading.

13. Read test accurately at a temperature of 130 degrees F.
14. Record test as read, opposite patron's name.

TESTING SKIMMILK AND BUTTERMILK

In general, skimmilk and buttermilk is tested with the Babcock test in the same manner as whole milk except double-neck test bottles are required which are especially constructed for this purpose. The skimmilk test bottle differs from the whole-milk test bottle in having two necks, one of small bore graduated to read to one-hundredth percent for the fat column, and one extending nearly to the bottom of the bottle for filling.



A skimmilk test bottle.

Measure the liquid into the test bottles with the 17.6 cc. pipette used for whole-milk testing. Use about 26 cc. (1½ measures) of sulphuric acid instead of 17.5 cc. as in whole-milk testing. It is better to add the acid in two portions of about 13 cc. each, shaking after each addition. Great care must be taken while shaking to be sure that no particles reach the fat tube. The first whirling should be for ten minutes. The rest of the test is conducted as in whole-milk testing. If the fat is in the lower part of the tube it may be forced into the graduated part by the pressure of the finger at the mouth of the filling tube. The skimmilk test is valuable for testing the completeness of the skimming and should a test fail to reveal the presence of butterfat, it is an indication that the testing was poorly done and should be repeated as all skimmilk contains some butterfat.

WHY MILK TESTS VARY

The percentage of fat in normal milk varies a great deal from milking to milking and from day to day. Wide variations are puzzling and are usually looked upon with suspicion, while in reality it is quite natural for butterfat tests to vary. Anderson of the Michigan Agricultural College studied 200 seven-day records made under ordinary herd conditions, and 2,000 seven-day advanced registry records and found that one may expect, during seven consecutive days, the cows in a herd to vary in the percentage of butterfat in the milk at different milkings, about as follows: 30 percent of the cows will vary 1 percent or less, 50 percent of the cows will vary 1.1 to 2.0 percent, 14 percent will vary 2.1 to 3.0 percent, while the remaining 6 percent will show a much greater variation, even as much as 3 percent. In other words, we need not be surprised if 6 percent of the cows in the

herd yield milk that tests 3 percent of fat at one milking and 6 percent at another milking. Applying these figures to a herd of 100 cows, the average variation for the entire herd would be 1.5 percent and small herds will not come true to the average so the herd milk may be expected to vary from time to time.

All of many causes of these variations are unknown but the following are the main factors which cause the fat contents of milk to vary:

Individuality of Cows.—Some cows have the inherent ability to produce milk of a higher butterfat content than others.

Breed of Cows.—All breeds of dairy cattle do not produce milk of the same butterfat content. The average butterfat composition of milk for the different dairy breeds is as follows: Jersey, 5.35 percent; Guernsey, 4,98 percent; Brown Swiss, 4.24 percent; Shorthorn, 4.05 percent; Ayrshire, 3.66 percent, and Holstein, 3.45 percent.

Time Between Milkings.—The greater the interval between milkings, the lower the test of the milk, and the shorter the interval, the higher the test. There is a tendency for the morning's milk to test higher in fat content. If the interval between milkings is 10 to 14 hours, one may expect a variation in fat percentage of the two milkings of from .5 to 1 percent.

Complete Milking.—If part of the milk is left in the cow's udder the percent of fat will be low, due to the fact that the last part of the milk is especially rich. Van Slyke at the New York station found that the first milk drawn from a Guernsey cow contained but .76 percent fat, the second, 2.60 percent, the third 5.35 percent and the last, 9.80 percent.

Weather Conditions.—It has been shown that the tendency is for cows to give milk richer in fat in cold weather. During the hot summer months, the milk generally contains less fat. Cows exposed to severe weather conditions will shrink in milk flow and may yield milk low in fat.

Season of Year.—No matter when a cow freshens, the tendency is for her to give milk richer in butterfat during the winter months, and with a lower test during the summer. When spring comes, there is always a drop in tests and milk plants have come to expect complaints about tests at this time of year. Cows that freshen in the fall will produce more milk and butterfat than those that freshen in the summer.

Physical Condition.—Cows in high physical condition at time of calving will give milk containing 1 to 2 percent more butterfat than normal. Cows that are sick or off feed may produce milk that is either high or low in test.

Stage of Lactation.—The first month after freshening the cow usually gives richer milk than during the following month or two. The fat percentage then usually remains fairly constant until toward the close of the lactation period, when it gradually

increases. The cause of this gradual increase in fat is thought to be due to a decrease in the flow of milk and the fact that the production of fat by the mammary glands appears to be more constant than the production of milk, so uniform fat production is continued by means of a higher percentage of fat.

Age of Cow.—The annual yield of both milk and fat by a cow normally increases from the first lactation until she is mature. Maximum production is usually reached at from 7 to 9 years of age, although the 3-year-old production is usually not much greater than the 2-year-old because of teething. After studying all the available data on the effect of age of the cow on the yield and fat content of milk, Eckles found that on the average, a two-year-old may be expected to produce about 70 percent, a three-year-old, about 80 percent, and a four-year-old, about 90 percent of the milk and butterfat she will produce under the same treatment when mature. A good dairy cow usually shows no marked decline in production until after 12 years old.

Influence of Feed.—If a cow receives sufficient nutrients to maintain her body weight, the percentage of fat cannot materially change for any considerable period of time by greater or less liberality of feeding or by supplying any particular kind of feed. Cows that are greatly underfed may produce milk somewhat lower in fat percentage than normal. All experiments conducted up to the present time show that there is no positive evidence of any continued direct effect of a feed in stimulating milk production or increasing the percentage of fat. No kind of feed or care will cause a Holstein to give milk rich in fat like the Jersey. However, a cow may be fattened before freshening and caused to milk off this body fat in the first month of lactation, thereby raising the percent of butterfat in her milk.

CREAM STATION INFORMATION

By the term "cream station", we refer to the place of business, the room or building, in which purchasing agents known as station operators receive, purchase or handle cream for sale or shipment.

Purpose.—Generally speaking the purpose of a cream station is to create a local market for the small cream-producer and to insure the creamery firm of a more steady cream supply.

The cream station has been a large factor in developing the dairy business in Colorado, especially in sections of the State where the herds are small, farms are far apart and the cow population is relatively small. The cream supply is naturally limited and it is impossible in such districts to operate a local creamery profitably.

Cream stations which are operated by intelligent and competent persons who are interested in the development and welfare of the dairy business, have proven an asset both to the producer and creamery.

Location of the Station.—Cream is a delicate food product capable of absorbing flavors and odors. It is important therefore, that the receiving station be so located that its surroundings are clean and free from objectionable odors and flavors. It is required that the station be located on a well-drained piece of ground, at least 50 feet from any contaminating surroundings. For business reasons, cream stations should not be located back of other buildings but located in buildings that are accessible to the farmer.

Size of Stations.—The size of a cream station will naturally depend upon the amount of business handled. The tendency in the past has been to make cream stations too small rather than too large, thus impeding the growth of the business. Under no circumstances shall the station contain less than sixty-four square feet of floor space.

Limited floor space handicaps the operator in his work, especially on busy days.

The following capacities and sizes give a fair estimate of the size of the building needed:

CAPACITY	SIZE
100 gallons per week	10 x 12 feet
250 gallons per week	14 x 16 feet
500 gallons per week	16 x 18 feet
1000 gallons per week	20 x 24 feet

Building or Room.—A separate room or building is required for the operation of any cream station and shall be used exclusively for the handling of dairy products.

Sanitary Surroundings.—Cream shall not be handled in connection with any business which is in any way contaminating by means of odors or otherwise. No new license will be granted

for the operation of a milk or cream station or any dairy plant in a building in which live poultry is handled, and firms renting space for such stations or plants should protect themselves in their contracts against live poultry being handled in the same building. After July 1, 1926, no renewal of a milk or cream station or dairy-plant license will be granted for operation in a building in which live poultry is handled.

Walls and Ceilings.—A clean, smooth, tight, well-painted, and washable wall-surface shall be provided. It is preferable to us a paint of light color. All stations where dimension lumber is exposed shall be ceiled and painted.

Floor.—The floor shall be water tight. A smooth, well-finished cement floor sloping to a drain, is the most desirable but a tight wood floor of well-matched lumber and painted is satisfactory if kept clean.

Light and Ventilation.—All stations shall have ample, natural light provided by means of doors or windows, and there shall be sufficient ventilation at all times of the year. The room or building shall have outside openings on at least two sides of the cream room and all stations except modern-type stations, established after July 1, 1923, are required to have one-tenth as much outside window space as floor space.

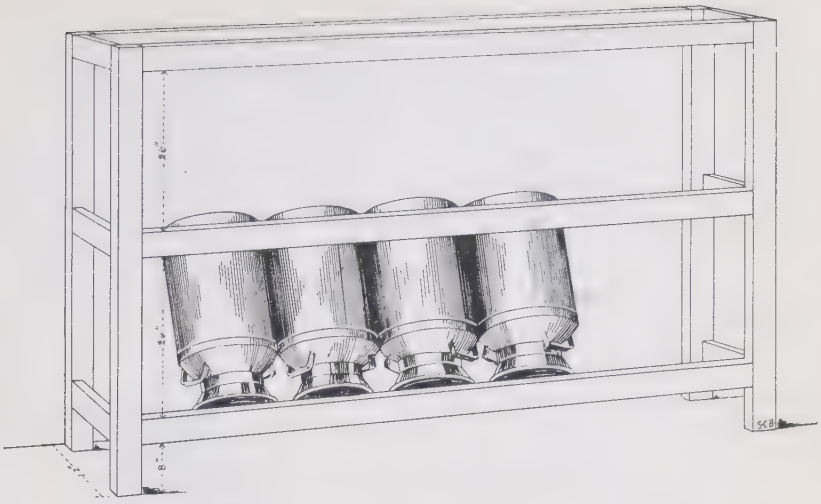
Screens.—All windows, other openings and doorways shall be screened during fly season with tightly fitting screens. Screens on doorways shall be provided with springs so that they will be self-closing. Fly season shall be calculated from May 1st to November 1st.

Drainage.—Suitable drainage should be provided by means of connections with sewer systems or cesspools, or all waste must be removed to a point not less than fifty feet from the building and if deposited on surface it is necessary that no nuisance shall be created.

Plumbing.—Where proper water system is available, stations should be provided with a supply of water and equipped with a sink for washing and cleaning properly, the same to be connected with suitable drainage.

CREAM-STATION EQUIPMENT

Can Rack.—The law requires that cream cans be removed from railroad depots within twenty-four hours after their arrival, covers removed and cans inverted in pure air. Naturally a can rack is necessary and said rack shall be built on the inside, not outside, and of sufficient size to hold all surplus, empty cans which are likely to be on hand at any time.



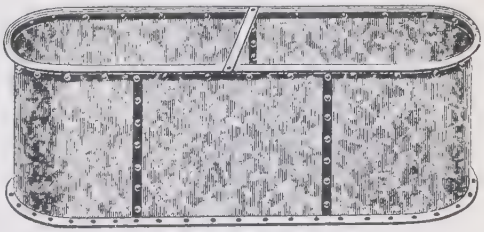
AN INEXPENSIVE, BUT WELL-MADE CAN-RACK.

A very convenient three-tier can-rack may be constructed very cheaply by constructing one of 2 x 4's and placing it against a wall as illustrated. The crosspieces on which the mouths of the cans rest should be about 12 inches from the wall and the lowest one should not be less than 8 inches from the floor. The space between tiers should be about 26 inches.

Nails in the racks opposite the can bottoms will serve as hangers for the lids in cases when the lids are not fastened to the cans.

The can rack should be made of dressed lumber and should be painted as it will not only improve the appearance of the station but will be easier to keep clean. If galvanized pipe is used as crosspieces in place of the 2 x 4's it will be found to be much more sanitary.

Cooling Tank.—Cream is a highly perishable product and in order to help preserve its quality, cooling tanks should be provided wherever there is an available water supply.



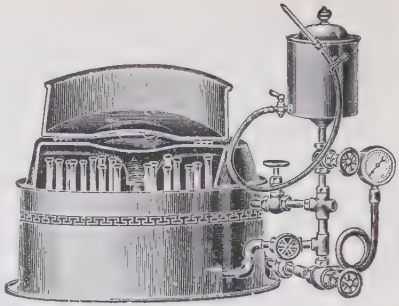
A GALVANIZED TANK SUITABLE FOR A COOLING TANK IF CONNECTED WITH A DRAIN.

Babcock Tester.—The Babcock tester, or centrifuge, in which the bottles are whirled should be set level and on a solid fondation in order that it may run smoothly. If the machine shakes it will

cause a remixing of the fat and consequently an inaccurate reading. A twelve-bottle tester is large enough for the average station.

Hot-Water Facilities. — An abundance of hot water is absolutely necessary to the successful operation of a cream station. A steam boiler or adequate facility for heating plenty of water is required. An upright tubular boiler with steam fittings and connections is the best and most efficient means of securing plenty of hot water. A boiler will also provide steam for running the Babcock tester. When stations are equipped with oil stoves, they must have at least two burners and the hot-water tank must have a heating capacity of at least three gallons.

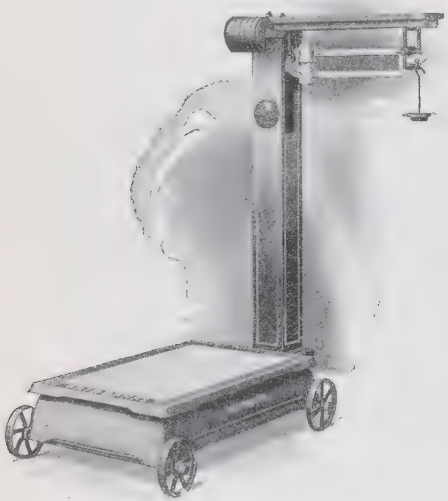
Wash Sink.—Where proper water system is available, cream stations should be provided with a supply of water and equipped with facilities for properly washing and sterilizing cream cans and other station equipment. Such equipment should be connected with a suitable drainage system. A sink made of half-round galvanized steel, large enough to hold a ten-gallon cream can, is suitable. The two-compartment sink, with steam jet for sterilizing, is recommended, since it enables the operator to wash properly, rinse and sterilize the cream cans, which aids in better quality.



A STEAM BABCOCK TESTER.



A STEAM BOILER

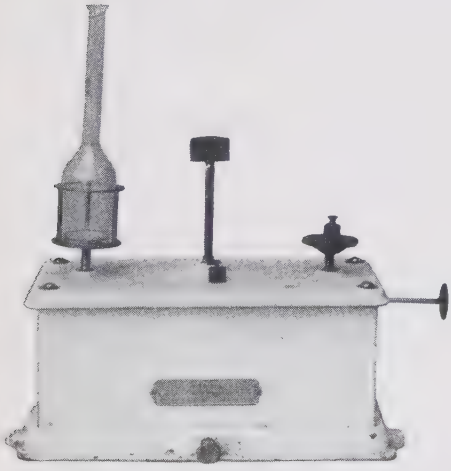


WEIGHING SCALES.

Weighing Scales.—The scales for weighing cream are pre-



A WASH SINK.



ONE BOTTLE TORSION SCALE.

ferably the platform type, and should have a capacity of at least two hundred pounds and the beam should be marked with the standard graduations.

Testing Scales.—All cream samples for testing must be accurately weighed on scales sensitive to at least ten milligrams. The cream scales should be balanced on a level, solid shelf fastened securely to the wall away from air drafts, or on a platform that is mounted on a 4 x 4 post that extends down through, but not touching, the floor and is set securely in the ground. If this kind of a platform is used, vibration is eliminated and samples can be weighed while the testing machine is running.

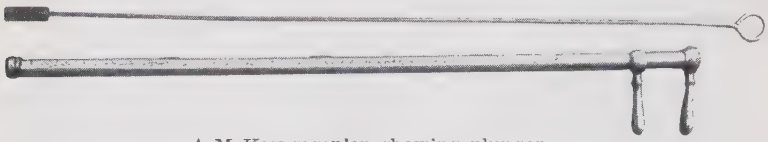
Test Weights.—The 9-gram weight is recommended due to the fact that the 9-gram bottles have been adopted. It sometimes happens that these weights are inaccurate. When in doubt on this point, the operator should have his weight checked by either the field man or the general office. The weights should always be kept free from dirt and grease, as any accumulation of dirt will result in an inaccurate test.

Stirring Rod.—A stirring rod is required in each station in order that the cream may be thoroughly stirred before sample is taken with the McKay sampler.



A stirring rod.

McKay Sampler.—The McKay sampler is a device for taking a sample of milk or cream for testing to determine the butterfat content of the milk or cream. To secure a representative and legal sample of cream according to the Colorado law, the sample must be taken with a McKay sampler, which is to be equipped with a stripper handle and a metal plunger. See page 41 for manner of using McKay sampler.



A McKay sampler showing plunger.



A dairy thermometer.

Thermometer.—In order that proper temperatures may be observed, an accurate dairy thermometer is required.

Waterbath.—In order that the proper reading temperatures may be maintained a waterbath is necessary and is required by law. The law requires that all tests shall be maintained in a waterbath for five minutes at a temperature between 120 and 130 degrees F. until read.

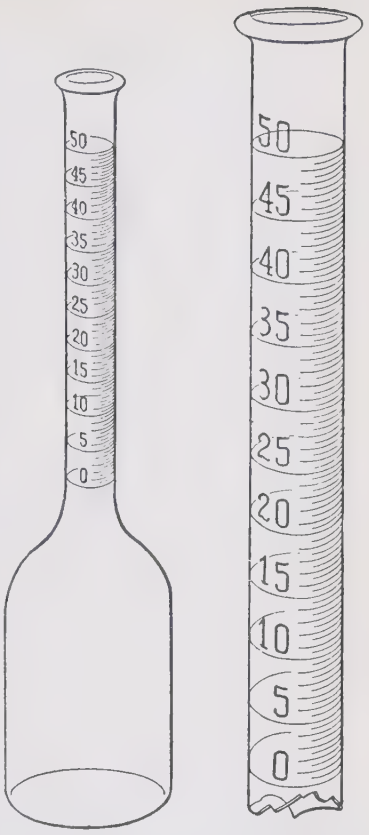
Cream Pipette.—The cream pipette will be found a convenient instrument to use in transferring the cream to the test bottle for weighing. Remember that cream tests are to be weighed, not measured.



Cream pipette

Test Bottles.—Cream-test bottles are of two sizes, 9 and 18 grams,

and are graduated to read the percentage of fat according to size. The 50 percent, 9-gram, 6-inch cream-test bottle is recommended and approved by the State Dairy Commissioner. The total percent graduation shall be fifty. The graduation shall represent 5 percent, 1 percent, and .5 percent. The charge of the bottle shall be 9 grams. The total height of the bottle shall be 6.5 inches. The capacity of the bulb up to the junction of the neck shall not be less than 45 cc.



A 9-gram cream-test bottle conforming to the requirements of the State Dairy Commissioner, and showing graduations.

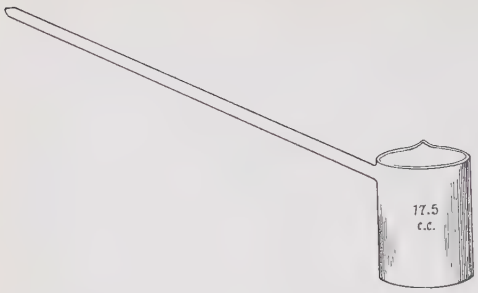
Dividers.—Dividers should be sharp-pointed and move with plenty of friction at the hinge, but not too tight as they spring and give incorrect reading. Dividers which are loose and likely to slip should be either repaired or discarded.

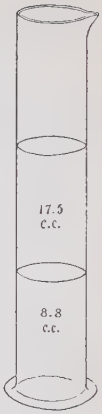
Acid.—For cream testing, commercial sulphuric acid with an acidity of 90.6 to 91 per cent, and a specific gravity of 1.823 to 1.825 is recommended as it seems to give the best results. All cream-testing acid may not be suitable for milk. No certain acid can be specified as being the best in all cases, due to the variations in creams, but for the best average results, acid between the limits just mentioned gives the best results.

Such acid should not be left in an open container, as the action of the air will very soon cause it to become weak and unfit for use.



Dividers used in measuring the butterfat column





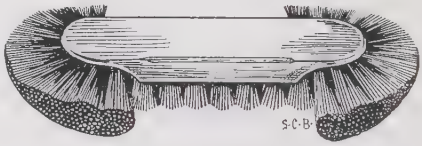
A GLASS ACID DIPPER AND ACID MEASURE.

Acid Measure.—The acid measure or dipper is a guide to the amount of acid to use and furnishes a convenient means of transferring the acid to the test bottle. The 9-gram acid measure or dipper is recommended.

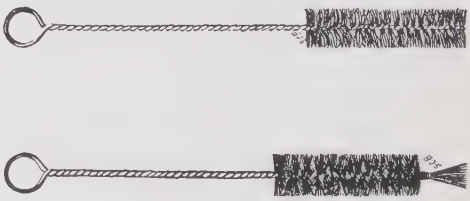
Sample Bottles.—Any wide-mouthed bottle holding enough for two samples is suitable. However, since operators are required by law to use the McKay sampler, it is best to equip station with four-ounce bottles. Any sample bottle that is used must have a tightly fitting top or cover to prevent evaporation of moisture. A cream station should have a double set of sample bottles as all tested samples are required to be held until the close of the next test day.



CREAM SAMPLE BOTTLE.



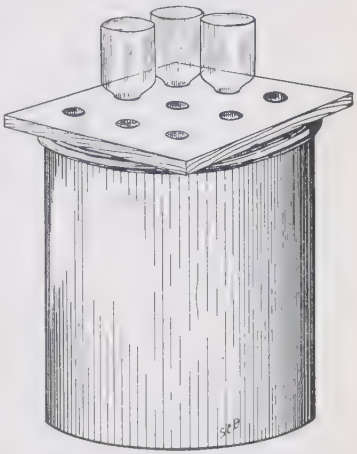
CAN BRUSH



TEST-BOTTLE BRUSHES

Brushes.—Test-bottle brushes are necessary for cleaning bottles in which dirt sticks badly. Can brushes are necessary in order that all cans may be thoroughly washed.

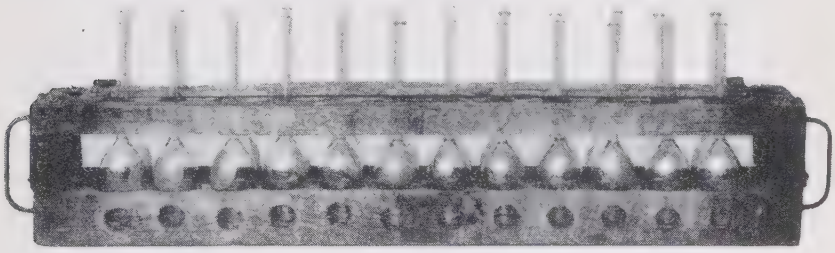
Waste Jar.—An earthenware jar with proper cover should be provided for disposing of the test when finished. A wooden cover, bored full of ⅞-inch holes through which the necks of the test bottles can be inserted and left to drain, will be found convenient.



AN INEXPENSIVE WASTE JAR FOR DRAINING TEST BOTTLES.

Bottle Rack.—By using a test-bottle rack, the bottles are easier to handle, will drain better and some of the breakage will be eliminated.

Glymol.—Glymol is a high quality of white mineral oil. It is best to use it colored. The purpose of glymol is to flatten the meniscus on top of the fat column and secure a straight and sharply defined line for reading. Use only a few drops of glymol and add it immediately before reading the test. Do not use glymol in reading milk tests.



A BOTTLE RACK.

Washing Powder.—A mineral washing powder is the only effective cleaner for station work. Soap will not do the work required.

Supplies.—Clean towels or cloths should be provided for the station operator. Station should be equipped with a broom and mop in order that the operator may keep the floors clean.

MODERN TYPE STATION

In many localities in the State, too much competition has had a demoralizing effect on the cream-station system. An instance can be cited: Eight creamery companies opened up stations at the same shipping point; this resulted in a division of the

cream and reduced the cream available to each concern, thus multiplying the expense of handling the cream and increasing the cost of securing the butterfat, which was a loss to the farmer.

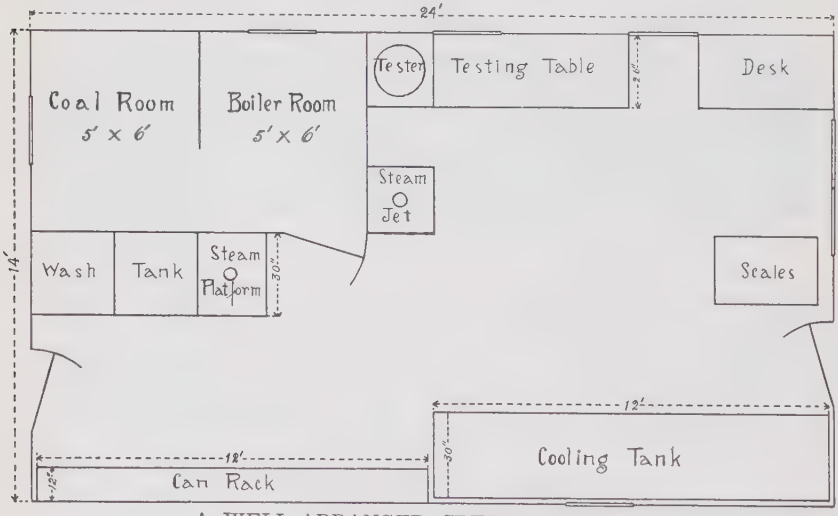
Another factor that has a demoralizing effect on the dairy industry is the establishment of cream stations in towns by a few firms during the flush season. Usually the stations are started in undesirable locations, lack the proper facilities for receiving and handling the cream and are not properly equipped for cleaning cans and other utensils.

You can readily see that this type of station is a distant detriment to the dairy industry and in order to secure the proper operation of cream stations and to put same on a permanent basis, the State Dairy Commissioner issued the following regulations pertaining to cream-receiving stations that were effective June 1, 1923:

REGULATIONS

When Required.—It is desirable that all new stations should be of this type when possible, and whenever a new station is to be erected in a town already having two or more, it must be of this type, and conform to the following requirements:

Kind of Room or Building.—A separate room or building is required for the operation of a cream-receiving station, and adequate floor space is required. It is recommended that such room or building shall not contain less than 192 square feet of floor space. The room or building shall have outside openings on at least two sides to provide proper ventilation. The main entrance shall face the street, and there shall be no windows or doors into other rooms, unless to office, boiler room, or can-rack room.



A WELL-ARRANGED CREAM STATION.

Sanitary Surroundings.—The surroundings of a cream station should be sanitary in every sense of the word, as cream readily absorbs any undesirable odors, and decayed substances harbor flies. Stations shall not be

located within fifty feet of chicken yards, hog pens, or objectionable buildings or unsanitary conditions that cannot be removed. The outside portion of the station should be neat and clean in appearance, and provided with some sort of platform or sidewalk.

Walls and Ceilings.—A clean, smooth, tight,washable surface shall be provided.

Floor.—The floor shall be of cement with a smooth finish, and extend so as to form a concrete base-board, and floor shall be properly drained and trapped, the drain to be connected with sewer system, septic tank, or covered cesspool, or delivered through closed drain with trap. Where sewage is deposited on surface which shall be not less than fifty feet from building, it is necessary that no nuisance shall be created.

Light and Ventilation.—All cream stations shall have ample light, and it is recommended that there be one-sixth as much window space as floor space.

Screening.—All windows, other openings and doorways shall be screened during fly season with tightly fitting screens. Screens on doorways must be self-closing. Fly season shall be calculated from May 1st to November 1st.

Equipment.—Equipment shall consist of:

1. Can rack inside of station of sufficient size to hold all surplus empty cans.
2. Cooling tank of sufficient capacity to hold all cream received in one day's business. This may be remitted by special permission where water supply is inadequate.
3. Babcock tester.
4. Steam boiler or adequate facilities for heating plenty of water.
5. Wash sink with proper drain.
6. Platform scale, capacity 200 pounds or over, with standard graduations.
7. Test scales sensitive to ten milligrams.
8. Stirring rod.
9. McKay sampler equipped with stripper handle and metal plunger.
10. Dairy thermometer.
11. Waterbath.
12. Cream pipette.
13. Test bottles.
14. Dividers with sharp points or edges.
15. 9 cc. acid measure or dipper.
16. Sample bottle (4 oz.)
17. Test-bottle brush.
18. Test-bottle rack.
19. Separate receptacle for emptying test bottles.

Supplies.—Supplies shall consist of: 1. Sulphuric acid of standard required by State Dairy Commissioner.
2. Colored glymol or other approved reading oil.
3. Washing powder.
4. Clean towels and cloths.
5. Broom and mop.

METHODS OF RECEIVING CREAM

The primary function of the operator of a receiving station is to buy cream and his success depends on his personality, business methods, and the condition in which he keeps his place of business and equipment. The best cream buyers are those who have made it their business to become generally informed on the

subjects of dairying and dairy problems. His intimate acquaintance and association with the cream producer places him in a position to offer helpful suggestions which are bound to result in a better and more economical production on the one hand and a decided improvement in the quality of cream on the other. In other words, his station becomes a dairy service station.

Nearly every person has a particular business method of his own which he follows. Some never get the habit of doing work systematically.

The following steps will serve as a guide and aid to all who are just taking up this work, and the suggestions may be worth the consideration of older followers of the business:

1. Write the patron's name plainly upon the receiving sheet.
2. Balance the weighing scales.
3. Weigh the cream carefully.
4. Record the gross weight of cream and can.
5. Note the appearance and quality of the cream.
6. Sample as required by Colorado law.
7. Place the number of the sample bottle after the patron's name.
8. Empty cream into company can.
9. Rinse the patron's cream can thoroughly, but do not use an excessive amount of hot water.
10. Wash patron's can thoroughly, sterilize and drain it.
11. Weigh the empty can for tare weight.
12. Record weight of empty can. In case there is no space on the receiving sheet for the tare weight, subtract the weight of empty can from the gross weight of the can and cream obtained in step No. 4, and enter the remainder on the receiving sheet as the weight of the cream paid for.
13. Return can to patron, at the same time handing him a check for the previous delivery, and also a statement of the amount of cream and grade just received and the price being paid for butterfat.

The common practice is to pay the patron for his cream the same day that he delivers it. This is not desirable and is not recommended, for the reason that when an operator is rushed he is not apt to do so careful and accurate work.

SAMPLING CREAM

The sampling of milk and cream for butterfat tests is one of the most delicate problems with which the station operator has to deal. It is the most difficult and important step in the butterfat determination. If a proper sample is not obtained, the ultimate test will not be correct, no matter how carefully the succeeding steps may be carried out.

How to mix the cream.—The purpose of thoroughly mixing the cream before sample is taken is to cause every portion of it to be alike in fat content, so that any sample taken out will be

representative in fat content of the entire container. To accomplish this, stir the cream thoroughly with the stirring rod, giving the cream a vigorous boiling motion. Be sure to scrape the sides and shoulders of the can, because thick heavy cream is likely to stick to the sides of the can. Making sure that these scrapings are thoroughly mixed with the other portions of the cream, and sample immediately with McKay sampler.

Heavy and Frozen Cream.—It is hard to secure a representative sample from thick, lumpy, or frozen cream. Such cream should be gradually heated to 110 degrees in a waterbath until, by continuous pouring and stirring, the body of the cream has become smooth, free from lumps and of a uniform texture. If the above steps are not followed before securing sample you will not have a true or representative sample.

How to take Sample.—To secure a representative and lawful sample, the McKay sampler must be used. For those who are not familiar with the McKay the following suggestions may help:

1. To get a sample which represents the average quality, the milk or cream delivered must be thoroughly stirred.
2. See that all openings of the sampler are closed, and the plunger is drawn back.
3. The sampler is then lowered into the cream to the bottom of the can, when it is opened to allow it to fill, and then closed again.
4. After it is filled raise the sampler from the can, lowering the stripper handle as you remove the sampler, so that all cream adhering to the outside of the sampler is cleared off.
5. In emptying the sampler, the handles are manipulated to leave a small opening at the bottom, and the plunger is pushed down to force the cream out of the tube into a clean, dry, sample bottle that is equipped with an air-tight cover. In case your sample bottles are not large enough to hold the full charge of cream, you might empty the charge of cream into ordinary tin cups. Pour the cream from one cup to another several times until it is thoroughly mixed and then fill sample bottles. Be sure that the cups are thoroughly washed after sampling each patron's cream.
6. Wash the sampler in hot water and hang up to drain after each patron's cream is sampled.

Note:—It may seem troublesome or unnecessary to go to all detail mentioned above, in order to secure a sample, but it is well to remember that your right to do business depends upon your giving a correct test to the producer.

Care of Samples.— All milk and cream samples shall be kept tightly covered to prevent evaporation of moisture. After the samples of cream received during the course of the day's business have been tested, they shall be retained or held in tightly

covered, properly labelled sample bottles until the close of the next test day, preferably in a cool place.

CREAM TESTING

The Babcock test is the most satisfactory and practical means of determining the amount of butterfat in milk or cream. The point never to be lost sight of in testing milk or cream is that the small quantity taken for the test must be truly representative. No matter how carefully the test is carried out, if the sample taken does not accurately represent the milk or cream to be tested, the results will be inaccurate and worthless.

When to Test.—Testing should be done at the time when the operator is least likely to be disturbed, as they are responsible for correct returns to the producer. To make a lawful test it will require at least 25 or 30 minutes.

Balance Test Bottles on Scales.—While your cream sample is heating, mark each test bottle plainly with the same number given the corresponding sample bottle. Place the test bottle in the left-hand holder and balance the scale carefully with the bottle on it. (This is done by moving the counter weight back and forth until the point of balance is found.) Put the 9-gram weight on the right-hand pan. Always lock the scales before placing or removing bottles or weights from them.

Preparing Cream Sample for Testing.—The preparation of cream for testing does not differ materially from that of milk. Cream samples should be heated in a waterbath until the cream has reached a temperature between 65 and 75 degrees F. Then mix sample thoroughly by shaking or pouring from one bottle to another until the cream is uniform in color, smooth and free from all lumps. The sample then should be taken quickly for testing.

In the case of cream sample in which the fat has become separated, frozen, churned, or changed into a tough, leathery condition, it is heated to a temperature of 110 degrees F. to melt the fat, after which it is continuously shaken until cooled to 70 degrees F. or lower, and then the sample is taken and weighed as quickly as possible. Agitation during the process of cooling is essential to keep the melted fat from separating so rapidly as to prevent obtaining a uniform mixture.

Weighing Test.—Your scales and bottles in balance, the next step is to transfer, by means of a wide-mouthed pipette, enough of the thoroughly mixed cream to the test bottle to bring it again in the balance with the 9-gram weight. No cream should be allowed to get on the outside of the bottle or on the scale pan while weighing. If too much cream should be added to the test bottle, the excess may be removed with a clean wire or glass rod. Be careful that the test is weighed accurately.

To insure accuracy, all samples of cream should be tested in duplicate. If the results of the duplicate tests do not agree, there is an error somewhere and the work should be repeated.

Adding Acid.—Before adding acid to the cream in test bottle be sure that it is of the same temperature as the cream. Unless the cream and acid are brought to the same temperature (between 65 and 75 degrees) at the time of mixing, the action of the acid may cause burnt or cloudy tests. Add about 9 cc. of the proper strength of concentrated commercial sulphuric acid. This acid is then added carefully by inclining the test bottle at an angle and pouring the acid slowly and carefully into the bottle, at the same time revolving the bottle so that the acid may wash down all traces of cream which have been left in the neck of the bottle.

Rich cream will require a little less acid than thin cream, and sour cream will require a little less than sweet cream.

Mixing Cream and Acid.—After adding the acid, the next step is to mix the contents by a gentle rotary motion, avoiding spilling or shaking acid particles into the neck. Incomplete mixing invariably means a poorly made test. After mixing, each bottle should be allowed to stand a short time, until the desired uniform color is obtained. In case of strong acid sometimes it is necessary to add a small amount of hot water to check the action of the acid.

Adding Hot Water.—Before adding the hot water give the bottles a second gentle rotary motion. Then carefully add enough clean, hot, soft water of 180 degrees F. to fill the bottle up to the neck. Do not pour the hot water directly on the fat column but incline the bottle at an angle and add the water slowly and carefully. If soft water cannot be obtained, add a few drops of sulphuric acid to the hard water before putting into the bottle. The use of hard water will cause air bubbles on top of the fat column.

Whirling.—The test bottles must be placed in the testing machine or centrifuge so that they will be evenly balanced and whirl for five minutes at the proper speed, according to tester. The periods of whirling given mean the time during which the tester is run at full speed, and do not include the time used in starting and stopping machine. See page 24 for table for different sizes of testing machines.

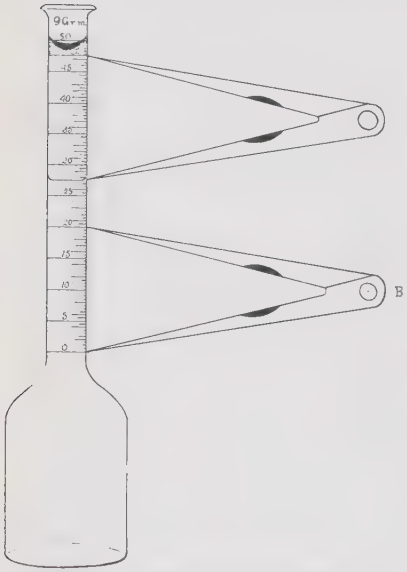
Adding Hot Water the Second Time.—After running the machine for five minutes, stop and add enough water of a temperature of 180 degrees F. to each bottle so that all butterfat floats within the graduated scale.

Second Whirling.—After the hot water has been added the second time, the bottles should be whirled for two minutes.

Reading Temperature.—After the second or two-minute

whirling, remove the test bottles from the machine and place them in a hot waterbath for at least five minutes, the temperatures of the water should be between 120 and 130 degrees F., and water shall be deep enough to surround the fat in the necks of all bottles. All tests shall be maintained at the temperature mentioned above until read.

Reading Test.—If the test has been properly run, the butterfat column should be a clear golden-yellow or straw-color liquid without any curd or sediment at the base or scum on top. If the butterfat column is as it should be, take one test bottle from the waterbath and add a few drops of glymol and read immediately. Glymol must not be dropped in, but must be allowed to flow down the side of the neck. In reading the test, hold the bottle perpendicular and on a level with the eye. The test is then measured by means of sharp-pointed dividers, by placing one point of the dividers at the bottom of the lower end of the fat column or meniscus and the other point at the top of the fat column, which is the division line between the butterfat and glymol. The dividers are then carefully lowered until the lower point of the dividers rests on the zero graduation around the neck of the bottle and the point to which the upper arm of the dividers reaches is noted and read. It is well to recheck this operation to be sure the dividers have not slipped. All readings should be read to the nearest one-half percent indicated on the scale on the test bottle. When reading is completed it should be recorded opposite the patron's name, being sure that the number on the test bottle corresponds to the number given the patron's name.



METHOD OF READING CREAM TESTS.

DIFFERENT STEPS IN CREAM TESTING BRIEFLY TOLD

1. Heat sample to a temperature between 90 and 110 degrees F.
2. Balance test bottles on scale.
3. Mix sample thoroughly.
4. Weigh test or tests accurately.

5. Cool tests to temperature of between 65 and 75 degrees F.

6. Add acid of same temperature. (About 9 cc.)

7. Mix well with a gentle circular motion. (Let set until coffee brown color is obtained.)

8. Add hot water of temperature of 180 degrees F. up to neck of bottle.

9. Whirl five minutes at proper speed, according to tester.

10. Add hot water of temperature of 180 degrees F. until all butterfat floats within the graduated scale.

11. Whirl two minutes.

12. Place test bottle into hot waterbath, maintained at a temperature of 120 to 130 degrees F. for five to ten minutes. (The water in the bath should surround the fat column.)

13. Add carefully about three drops of colored glymol or colored reading oil as each test is read.

14. Read test by measuring with sharp-pointed dividers from bottom of butterfat column to the division line between the butterfat and glymol.

15. Read tests carefully.

16. Record tests as read opposite patron's name.

LICENSES AND PERMITS

License Required by Law.—In section 9 of the Colorado Dairy Code, as amended by the twenty-fourth general assembly, March, 1923, provision is made requiring that any person desiring to sample or test milk, cream, or other dairy products for the purpose of determining the value of such products when bought and sold, shall hold a license granted by the State Dairy Commissioner.

License Fee.—The same section of the Colorado Dairy Code mentioned above provides that all persons who secure a sampler's or tester's license must pay a license fee of three dollars ($3.00) for the testing year or any part of a year.

When to Pay License Fee.—The three-dollar license fee must accompany the application for examination or application will not be accepted. Make draft or postoffice money order payable to State Dairy Commissioner.

License Fee Refunds.—All money collected by the Dairy Commissioner is turned over to the State Treasurer and no refund will be made.

How to Make Application.—Write to the State Dairy Commissioner, Fort Collins, Colorado, for an application blank for examination, or secure one from the fieldman of the creamery that engaged you. Fill out the application properly, attach license fee and mail to State Dairy Commissioner, Fort Collins, Colorado.

All applicants for examination must be at least 16 years of

age, and must have tested, prior to the time of their application, at least ten samples of milk or cream under the supervision of a licensed operator, or a creamery field superintendent, and according to the directions printed in this bulletin.

Statement of Applicant.—If inspection shows that applicant made any mis-statements on application blank, his license will be cancelled.

When to Start Operating.—All newly employed operators, whether samplers or testers, must have their applications in the State Dairy Commissioner's office and hold receipt that application has been received and accepted before starting operations. To start operating before you secure permission from the State Dairy Commissioner is a violation of the Colorado Dairy Code.

Substitutes.—The best method of solving the substitution problem in case of sickness or important business at a distance, is to have some member of the family or a friend hold a license so that he may readily fill the vacancy made by such an unexpected absence. The regular operator's license is subject to cancellation in case he leaves the station in charge of an unlicensed person. When there are two or more licensed operators in a plant, each operator is required to place his initial on the daily report after all samples tested by them.

Written Examination.—As soon as application for examination is received at the office of the State Dairy Commissioner, notice will be sent to the applicant to appear for the examination within seven days from date of notice, before the justice or notary named in the application. As soon as the examination has been taken and returned from the notary, the papers will be gone over and carefully graded. If a passing grade is earned, a license will be issued subject to further examination by a representative from the Dairy Commissioner's office.

The license will be mailed with a report showing the grade secured on the examination and a receipt for the license fee if it was paid by the applicant. In case the fee was paid by some other party the receipt will be mailed to him.

Practical Examination.—After a license has been issued on written examination, a personal examination will be given by a representative from the Dairy Commissioner's office. The examnation will cover such points as the condition of the station, a demonstration of the testing work, and a review of some important points in this bulletin pertaining to your station work.

Failure on Examination.—If applicant fails to make a passing grade on the first examination taken before a notary public, a notice of failure will be sent to the person failing and a second examination will be granted five days from date of notice.

Applicants that fail on second written examination or on practical examination will not be granted a license or permitted

to do testing. Permit issued upon receipt of application for examination will be cancelled at the time the applicant is notified by the office of such failure, and another application for examination will not be accepted within 90 days from date of failure.

Milk and Cream Samplers.—Occasionally persons sample milk and cream but do not test same for butterfat content. Such persons will be required to take the same examination as the testers. Sampling is considered the most important step in determining the butterfat content of milk and cream. It is essential and necessary that samplers have a thorough knowledge of testing work.

Examination Questions.—Examination questions will be taken from the list given on pages fifty-one to fifty-eight inclusive.

How Long License Is Valid.—Sampler's or tester's licenses are valid from date of issue until the following June 30th, subject to cancellation by the State Dairy Commissioner at any time that he shall find that the person holding said permit is incompetent or guilty of violating any of the provisions of the dairy laws or regulations.

License Posted.—Every operator is required by law to keep license or permit posted in his station or test room in plain view at all times.

Renewal of License.—Application for renewal of license will be mailed from the State Dairy Commissioner's office June 1 of each year and operators are requested to fill out renewal blank and return by mail with the necessary three-dollar license fee by June 15. This will give the office sufficient time to go over the applications, so that new licenses may be issued and be in your hands by July 1. No renewal will be made following the expiration of a license without another examination and then not for 30 days. If operators continue testing without a renewal, they will render themselves liable to prosecution.

Transfer of License.—Licenses or fees are not transferable; neither is it lawful for any person to sample or test under another person's license. In case an operator desires to transfer from one town to another or from one company to another, the State Dairy Commissioner must be notified in advance of change of location and receive notice of continuance of license. Otherwise operator's license is automatically cancelled.

Temporary Permits.—In case of emergencies such as death, sickness or resignation of an established operator, without notice, the field superintendent may procure the services of the best man available and instruct him thoroughly in the methods of testing. In case of this kind it is advisable to phone or wire and get permission for the new operator to start. Also see that the applicant's application and fee is in the mail before you leave the station.

When temporary permits are granted it is with the positive understanding that the party who receives the temporary permit is to take the regular examination for a sampler's or tester's license.

No temporary permit will be granted, under any circumstances, in connection with a cream station not previously established and in continuous operation.

INSPECTION

Provision is made by law for the inspection of all places where dairy products are handled or produced. This inspection will be made by a representative from the State Dairy Commissioner's office who will make written report of the conditions found, with recommendations. A duplicate copy of this report in case of the milk and cream station will be left with the operator. The original will be forwarded to the State Dairy Commissioner's office by the inspector.

Purpose of Inspection.—Inspections will be made from time to time, to cover such points as sanitation, testing work, and other points provided by the dairy laws and regulations.

Points Considered in Scoring a Station.—A plan of scoring receiving stations will be followed in order that the operator will know what to expect and can govern himself accordingly. Naturally an ideal station would score 100 percent. In order to determine the score of a station the ten points listed below will be considered and compared to an ideal condition:

1. **External Appearance. Points Allowed 10.**—A separate room or building is required for the operation of a receiving station. It should be located on a well-drained, slightly elevated piece of ground, sloping away from the station in all directions.

The room or building shall have outside openings on at least two sides to provide for proper ventilation. The outside portion of the receiving station shall be neat and clean in appearance and provided with some sort of porch or platform. If a frame building, it should be painted.

2. **Sanitary Surroundings.. Points Allowed, 10.**—The surroundings of the receiving station should be sanitary in every sense of the word, as milk and cream readily absorb any undesirable odors, and decayed substances harbor flies. Receiving stations should not be located within fifty feet of chicken yards, hog pens, or objectionable buildings or open rooms in which oils, poultry or other strongly flavored products are handled. The outside portion of the station should be neat and clean in appearance and provided with some sort of platform or sidewalk.

3. **General Equipment. Points Allowed, 10.**—All equipment mentioned on page 39 under heading of "Equipment and Supplies" is required for each receiving station except cooling tank or drain,

providing waste water disposed of does not create odor or attract flies. The cooling tank and drain is required of modern-type stations. In case of sampling station, the testing equipment is not required. The operator's permit or license and station permit or license shall occupy a conspicuous place on the wall. In case permit or license is not posted, the inspector shall grade operator zero on general equipment.

4. **Ventilation and Light. Points Allowed, 10.**—A receiving station shall have ample natural light, and it is recommended that one-tenth as much outside window space as floor space be provided, except in case of modern-type station which is one-sixth. Sunlight is an excellent disinfectant, and light is necessary if the operator is to do efficient work. Outside openings are required on at least two sides of the cream receiving room. A cool room is essential for keeping milk or cream.

5. **Drainage. Points Allowed, 10.**—Suitable drainage shall be provided by means of connection with sewer system, septic tank, or covered cess pools or all waste must be delivered through a closed drain with tap and deposited at a point not less than fifty feet from the building.

6. **Freedom From Flies or Vermin. Points Allowed, 10.**—All windows, other openings and doorways shall be screened during fly season with tightly fitting screens. Screens on door ways shall be self closing. Fly season shall be calculated from May 1 to November 1.

7. **Neatness of Interior. Points Allowed, 10.**—A well-arranged, neat station facilitates the operator's work. Suitable places must be provided for bottles, scales, etc., and articles kept therein. The receiving station shall be used exclusively for the handling of dairy products and at time of inspection if there is any other business being conducted in receiving room or any unnecessary materials or junk are found, the inspector shall make a severe cut.

8. **Walls and Ceilings. Points Allowed, 10.**—Walls and ceilings should be finished with a hard, clean, smooth, tight washable surface. Plastered surface is preferable. Tightly fitting boards painted in some light color are next in desirability. The surface must be kept clean and free from dirt.

9. **Cleanliness of Floor. Points Allowed, 10.**—The floors shall be water-tight. A cement floor is the most desirable floor as it can easily be kept clean. Tightly fitting, well painted boards are satisfactory, and must be kept free from dirt at all times.

10. **Cleanliness of Utensils. Points Allowed, 10.**—All station utensils must be kept scrupulously clean at all times. No excuses will be accepted. Stirring rod, McKay sampler, sample jars, test bottles, pipettes, and all vessels coming in contact with

the cream must be washed thoroughly each day. The personal appearance of the workman is also considered here.

CLASSES OF STATIONS

By the above method of scoring and inspection, the stations will be graded into five general classes as follows:

A+ 90 to 100—A clean, attractive, well-equipped and well-kept station.

A 85 to 89—good.

B+ 80 to 84—fair.

B 70 to 79—poor.

C Below 70—undesirable.

Should the station score 70 percent or less or show evidence of neglect or carelessness on the part of the operator, but show no violation of law, it will be rated undesirable, and the letter "C" will be stamped in bold-face type upon the license.

All stations rated in class C will be given a written notice of a time limit set for them to make class B or better. Such notice may be for one hour or fifteen days. If upon inspection after the time limit has expired, the station does not make class B or better, the station will be closed.

When station is decidedly unsanitary, the permits or license held are not posted in a conspicuous place, or other provisions of the dairy law are violated, the license or licenses will be cancelled and the station closed.

The purpose of this system is to carry on the inspection work in a business-like manner so that all stations and operators are treated alike and to improve the quality of Colorado butter by raising the standard of cream production and cream handling.

INSPECTION OF DAIRIES

The dairies furnishing the milk and cream going into these stations will be scored in a similar manner, and by building up the places where the cream is produced and handled before the raw material reaches the place of manufacture, a far-superior product of butter will be produced. The production of a high-grade butter in Colorado means an increased demand which in turn, means larger profits for all concerned in supplying such a market.

When dairies are scored the following score card will be used.

EQUIPMENT.	SCORE Perfect	SCORE Allowed
COWS.		
calth	6	
Apparently in good health	1	
If tested with tuberculin within a year and no tuberculosis is found, or if tested within six months and all reacting animals removed	5	
(If tested within a year and reacting animals are found and removed)		
ood (clean and wholesome)	1	
ater (clean and fresh)	1	
STABLES.		
ocation of stable	2	
Well drained	1	
Free from contaminating surroundings	1	
onstruction of stable	4	
Tight, sound floor and proper gutter	2	
Smooth, tight walls and ceiling	1	
Proper stall, tie, and manger	1	
rovision for light: Four sq. ft. of glass per cow	4	
(Three sq. ft., 3; 2 sq. ft., 2; 1 sq. ft., 1. Deduct for uneven distribution.)		
edding	1	
entilation	7	
Provision for fresh air, controllable flue system	3	
(Windows hinged at bottom, 1.5; sliding windows, 1; other openings 0.5.)		
Cubic feet of space per cow, 500 ft.	3	
(Less than 500 ft., 2; less than 400 ft., 1; less than 300 ft., 0.)		
Provision for controlling temperature	1	
UTENSILS.		
onstruction and condition of utensils	1	
ater for cleaning	1	
(Clean, convenient, and abundant.)		
nall-top milking pail	5	
ilk cooler	1	
ean milking suits	1	
ILK ROOM OR MILK HOUSE.		
ocation: Free from contaminating surroundings	1	
onstruction of milk room	2	
Floor, walls, and ceiling	1	
Light, ventilation, screens	1	
parate rooms for washing utensils and handling milk	1	
cilities for steam (Hot water, 0.5.)	1	
Total	40	

METHODS.	SCORE Perfect
COWS.	
Clean (Free from visible dirt, 6.)	8
STABLES.	
Cleanliness of stables	6
Floor	2
Walls	1
Ceiling and ledges	1
Mangers and partitions	1
Windows	1
Stable air at milking time	5
Freedom from dust	3
Freedom from odors	2
Cleanliness of bedding	1
Barnyard	2
Clean	1
Well drained	1
Removal of manure daily to 50 feet from stable	2
MILK ROOM OR MILK HOUSE.	
Cleanliness of milk room	3
UTENSILS AND MILKING.	
Care and cleanliness of utensils	8
Thoroughly washed	2
Sterilized in steam for 15 minutes	3
(Placed over steam jet, or scalded with boiling water, 2.)	
Protected from contamination	3
Cleanliness of milking	9
Clean, dry hands	3
Udders washed and wiped	6
(Udders cleaned with moist cloth, 4; cleaned with dry cloth or brush at least 15 minutes before milking, 1.)	
HANDLING THE MILK.	
Cleanliness of attendants in milk room	2
Milk removed immediately from stable without pouring from pail	2
Cooled immediately after milking each cow	2
Cooled below 50° F.	5
51° to 55°, 4; 56° to 60°, 2.)	
Stored below 50° F.	3
57° to 55°, 2; 56° o 60°, 1.)	
Transportation below 50° F.	2
(51° to 55°, 1.5; 56° to 60°, 1.)	
(If delivered twice a day, allow perfect score for storage and transportation.)	
Total	60

Equipment ..... + Methods ..... = ... Final Score

NOTE 1.—If any exceptionally filthy condition is found, particularly dirty utensils, the total score may be further limited.

NOTE 2.—If the water is exposed to dangerous contamination, or there is evidence of the presence of a dangerous disease in animals or attendants, the score shall be 0.

DAIRY-PLANT LICENSES

Required by Law.—Section 9 of the Colorado Dairy Code as amended March, 1923, provides that all milk and dairy-manufacturing plants and milk and cream receiving stations shall be licensed and pay a license fee.

How to Secure Dairy Plant License.—The law provides that upon application and payment of a yearly license fee, a temporary permit may be issued by the State Dairy Commissioner. The plant is then inspected and if it complies with the dairy laws and regulations, a license shall be granted. Application blanks will be furnished by the State Dairy Commissioner upon request.

License Fee Required.—The license fee for each milk or cream receiving station is two dollars ($2.00). The license fee for each creamery, condensery, cheese factory, ice-cream factory, milk plant, concentrator, or other dairy-manufacturing plant, is ten dollars ($10.00). All license fees must be mailed with application.

When to Start Operation of Dairy Plant.—It is unlawful to start operating any kind of a dairy plant before permission has been granted by the State Dairy Commissioner. Make application in due form, pay license fee and secure permit before starting.

License Required to Be Posted.—Creamery concerns are required to post dairy-plant permits or licenses in the plants designated on face of permit or license.

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QUESTIONS AND ANSWERS WHICH SUCCESSFUL APPLICANTS FOR A SAMPLER'S TESTER'S OR FIELDMAN'S LICENSE SHOULD KNOW.

All applicants should be prepared to answer any of the following questions regardless of whether they expect to be field superintendents or samplers or testers in a dairy plant. A full knowledge of all the sampling and testing work is necessary for all license holders. All persons are required to test at least ten samples of milk or cream under supervision of a person holding a license and according to the directions printed in this bulletin before taking the examination.

1. Q. *What is the purpose of the law requiring all persons sampling or testing milk or cream to be licensed?*

A. To assure the State Dairy Commissioner that the holder of the license is capable of properly sampling and testing milk or cream and is qualified to handle products in the best possible manner.

2. Q. *For what reason may a sampler's or tester's license be cancelled?*

A. License is subject to cancellation by the State Dairy Commissioner at any time that he shall find that the person holding said license is incompetent or guilty of violating any of the provisions or regulations of the dairy laws.

3. Q. *Is it necessary to prove intent to defraud in determining liability under the law in making false tests?*

A. No. The burden of the accuracy and correctness of the test lies upon the shoulders of the operator.

4. Q. *What is the penalty imposed upon any licensee for making false returns of butterfat contained in milk or cream?*

A. A fine of not less than $10.00 nor more than $200.00 and not over 60 days in jail for each offense is the penalty, and license can be cancelled.

5. Q. *When can an applicant start to sample and test milk and cream?*

A. No one can sample and test milk and cream until he has secured permission from the State Dairy Commissioner.

6. Q. *What should be done with a sampler's or tester's permit or license when received by applicant?*

A. The law requires that the permit or license shall be posted in the test room or station in plain sight.

7. Q. *How long is a sampler's or tester's license valid?*

A. A license is valid from date of issuance until the thirtieth (30th) day of the following June.

8. Q. *How can samplers or testers renew their license?*

A. Licenses may be renewed by paying a three-dollar

($3.00) fee and making application on blank form furnished by the State Dairy Commissioner.

9. Q. *When should a sampler's or tester's license be renewed?*

A. All licenses become null and void upon June 30 and must be renewed before that date. Even though previous license has only run a short time, the law does not allow anyone to test even for a week without having made application and paid fee.

10. Q. *What should be done in case a sampler or tester desires to change firms or locations?*

A. Licensee must notify the State Dairy Commissioner in advance of change of firms or location and receive notice of continuance of license, otherwise said license is automatically cancelled. Such transfer will not be granted to any licensee under investigation by the State Dairy Commissioner pending results of such investigation.

11. Q. *Where should a cream separator be kept?*

A. A separator should be kept in a separate dairy room or building provided for that purpose.

12. Q. *How often should a separator be washed and why?*

A. The bowl and all parts of a cream separator that come in contact with milk or cream should be washed and scalded after each separation. This is necessary to secure efficient separation and furthermore, dirty utensils are classed as unsanitary by law and must not be used.

13. Q. *What is the meaning of the term "unsanitary?"*

A. "Unsanitary" is a term fully defined in the law itself but, in general, means the same as insanitary.

14. Q. *How thick should cream be skimmed and why?*

A. Cream should be skimmed to a thickness of between 35 and 40 percent. Thick cream keeps better than thin cream. Also it saves express charges. More skimmilk is kept on the farm for feeding calves and pigs. If cream is skimmed too thick a thorough separation is not probable and some cream is lost in transferring from one vessel to another.

15. Q. *How can cream be skimmed near the same thickness each time?*

A. (a) Cream may be skimmed at approximately the same thickness each time by using the same amount of water to flush the bowl of the separator each time;

(b) By keeping the cream screw the same;

(c) By running the separator at the proper speed as designated by the manufacturer;

(d) By having the temperature of the milk the same;

(e) By keeping a uniform inflow to the bowl; and

(f) By washing the separator thoroughly after each time it is used.

16. Q. *Under what conditions should cream be kept on the farm?*

A. Cream should be kept in a cool sanitary place, the temperature should be below 50 degrees F. Odors of vegetables, oils, etc., must not be present. A spring house or a building provided with cold, running water is best. A cellar or cave is not a good place to keep cream because the air is seldom pure and the temperature is not low enough in summer.

17. Q. *How cool should cream be before it is mixed with other cream of previous skimmings?*

A. Always cool cream to between 40 degrees and 50 degrees F. before mixing with other cream. Stir thoroughly each time different batches are added together. Do not mix warm cream with cool. Do not mix warm and cool milk together.

18. Q. *How would you keep cream from souring?*

A. Produce clean milk. Use a clean separator. Cool cream promptly to 50 degrees F. or lower after separation. Never mix warm with cool cream. Keep each separation separate until day of delivery. Use proper care in delivering to market.

19. Q. *What is low-grade, filthy or unsanitary cream?*

A. Cream that has been produced under one or more of the following conditions is low grade: (1) Cream produced from milk drawn within eight days before or four days after calving; (2) Cream produced from milk drawn from cows that are kept in barns or stables which are not reasonably well lighted and ventilated; (3) Cream produced from milk drawn from cows that are kept in barns or stables that are filthy from an accumulation of animal feces: (4) Cream produced from milk which is drawn from cows which are themselves filthy or in an unhealthy condition; (5) Cream which has been exposed to foul or noxious air or gases; (6) Cream which has been kept exposed in dirty, foul or unclean places or under unclean conditions or where transmissable human disease exists; (7) Cream produced by the use of a cream separator that has not been thoroughly washed, cleansed and scalded after previous use: (8) Cream produced by the use of a separator placed or stationed in any unclean or filthy room or place; (9) Cream which, when delivered at the point of shipment, is more than three days old, during the months of May to October inclusive, or more than four days during the months of November to April inclusive. (10) Cream to which has been added any foreign substances, coloring matter, chemical or preservative.

20. Q. *What are the chief causes of bad flavors in milk or cream?*

A. Bad flavors in milk or cream are caused by unclean cows, dirty methods in milking, unclean utensils, insanitary surroundings, and some weeds and feeds.

21. Q. *How should milk or cream be taken to market?*

A. Take milk or cream to market in clean sanitary cans, well protected from the sun and road dust while delivering. In warm weather wrap dampened blankets around the cans and over the tops. In severe winter weather, milk or cream should not be permitted to freeze while delivering.

22. Q. *How often should cream be delivered to conform with the law?*

A. Cream should be delivered at least every three days during the months of May to October inclusive and at least every four days during the months of November to April inclusive.

23. Q. *State fully the method you use to secure a lawful sample of milk and cream?*

A. The law on sampling reads as follows: It is hereby required in making tests of milk or cream for the purpose of determining the value of such milk or cream when bought or sold, that the milk shall be poured from one vessel to another, and that cream shall be poured from one vessel to another at least three times before sampling, unless the said milk or cream is thoroughly stirred and sampled by the McKay Sampler, or some other recognized sampler that will secure a representative sample. The ordinary stirring rod commonly used is not a recognized sampler.

24. Q. *How soon after thoroughly mixing milk or cream should a sample be taken?*

A. Samples should be taken at once after mixing.

25. Q. *How large a sample should be taken?*

A. Two ounces is the preferred amount for a sample.

26. Q. *How should a can of frozen or lumpy cream be treated to secure a uniform sample?*

A. Cream should not be allowed to freeze. If frozen, place in waterbath of not over 110 degrees F. Warm until pouring a few times will give a smooth body, free from any lumps or streaks. Then take sample and cool cream as quickly as possible.

27. Q. *How should cream samples be treated immediately before weighing the test?*

A. Cream samples should first be heated in a waterbath to a temperature between 90 and 110 degrees F. Mix the sample thoroughly by pouring from one jar to another until cream is smooth and of a uniform color.

28. Q. *How should cream samples be cared for?*

A. Use clean bottles with tight seals and keep in a cool place.

29. Q. *How long should remainder of sample not used for test be kept?*

A. Keep remainder of all samples until the close of business on the following test day. This is a strict requirement.

30. Q. *Is the Babcock test accurate?*

A. Yes, it is if the method of operation is understood and care is taken to work it carefully.

31. Q. *Does the Colorado state dairy law impose a penalty upon any false determinations in testing*

A. Yes.

32. Q. *What is the correct rate of speed for 12 and 18-inch testing machines?*

A. For the twelve-inch machine, 980 revolutions is the correct rate; eighteen-inch machines, 800 revolutions. See page 24.

33. Q. *Are test bottles always correctly graduated and marked?*

A. They usually are, but instances have been noted in which they were false. The law imposes a penalty upon the sale or use of inaccurate glassware.

34. Q. *Why should cream be weighed into test bottles instead of measured?*

A. The specific gravity of cream varies with its fat content and other conditions. It is also difficult to transfer all of the cream in the pipette to the test bottle. Therefore, measuring will not give an accurate test.

35. Q. *What precautions should be observed in the weighing of cream tests?*

A. Use clean, sensitive scales, set level. Protect them from jarring and drafts while weighing. If any cream is spilled on the balance, remove it before weighing is completed.

36. Q. *What is the correct weight for cream tests?*

A. Nine grams is the correct weight.

37. Q. *How much sulphuric acid should be used when testing cream?*

A. Use enough acid so that the mixture of acid and cream has a coffee-brown color after mixing and standing one minute. Usually 8.8 cc. for nine grams is the amount required.

38. Q. *What kind and what strength acid should be used for cream testing?*

A. Commercial sulphuric acid, specific gravity 1.823 to 1,825 and acidity of 90.6 to 91 is standard.

39. Q. *At what temperature should cream and acid be before mixing?*

A. They should be at a temperature between 65 degrees and 70 degrees F.

40. Q. *What effect does acid have on milk or cream?*

A. Sulphuric acid dissolves all milk solids other than fat and liquefies the fat due to development of heat.

41. Q. *If the fat columns of the tests are either curdy, milky, dark or charred, what should be done and why?*

A. Make another test because either of the above conditions will cause an inaccurate and unlawful test.

42. Q. *What is the cause of curd in the fat column?*

A. It is caused by too wide a variation in temperature at time of mixing acid, milk or cream, or using too little or too weak acid.

43. Q. *What is the cause of milky fat column?*

It is caused by adding hot water too rapidly to the test after the mixture has cooled, or by letting the hot water fall directly upon the mixture instead of allowing the water to flow down the side of the neck of the bottle, or by allowing the mixture to stand too long before first water is added.

44. Q. *What causes bubbles of air on top of fat column and how can their presence be avoided.*

A. Air bubbles are due to hard water. Hard water may be softened by boiling or by the addition of a few drops of sulphuric acid.

45. Q. *What is the cause of a dark or charred fat column?*

A. Too warm milk or acid, or too much or too strong acid will cause it.

46. Q. *How do unclean bottles affect a test?*

A. Any adhering fat will make the test higher. Dark specks will also rise in the fat column when tests are made in dirty bottles.

47. Q. *How should test bottles be placed in testing machine?*

A. Bottles should be so placed in machine that they will balance each other when whirling.

48. Q. *How many minutes should cream test bottles be whirled in the machine?*

A. First whirling should be for five minutes, second, two minutes.

49. Q. *How should reading temperatures be regulated?*

A. Regulate them by placing the bottles in a hot waterbath of the reading temperature for at least five minutes. The water in the waterbath must surround the fat in the neck of the bottles.

A. See illustrations page 44.

50. Q. *At what temperature should cream tests be read?*

A. Read them at 130 degrees.

51. Q. *How should the length of the fat column be measused when reading cream tests?*

52. Q. *What is glymol?*

A. Glymol is a high quality of white mineral oil. It is best to use it colored.

53. Q. *How much glymol should be used and when should it be added?*

A. Use only a few drops of glymol and add it immediately before reading.

54. Q. *How should glymol be added?*

A. It must not be dropped in bottle but must be allowed to flow gently down the side of the neck of the bottle.

55. Q. *Why is glymol used in cream testing?*

A. It is used to remove the meniscus on top of the fat column and secure a straight and sharply defined line for reading.

56. Q. *Should glymol be used for reading milk tests?*

A. No.

57. Q. *State briefly the different steps to be observed in cream testing.*

A. Answer this question by stating the sixteen steps outlined on page 44.

58. Q. *What should you do when in doubt about the correctness of any part of your work?*

A. When in doubt, get in touch with the State Dairy Commissioner's office.

59. Q. *How should cream be cared for at the cream station?*

A. Cream brought to the station is under the licensed operator's care and it is his duty to keep it in the best condition possible. Empty the cream after careful weighing and sampling, into clean, well-aired cans. The cans of cream should be placed in a cooling tank or held at a temperature as near 50 degrees F. as possible. The cans should not be covered tightly but should be well protected from dust and flies. First-grade cream should not be mixed with poor-grade cream as such mixing will spoil the good cream. Every time more cream is added to a partly filled can, the entire amount should be thoroughly stirred. Frequent stirring is beneficial to the cream.

60. Q. *Can sour cream be tested?*

A. Yes, but cream in a sour or bad condition is much harder to sample and test accurately than sweet cream.

61. Q. *Should cans be borrowed from cream stations or creameries?*

A. Cans should not be borrowed from station operators or creameries, as in this way many milk or cream cans are not only lost, but others are returned in damaged and insanitary condition. The law forbids station operators to loan milk or cream cans bearing a trade mark or brand to their patrons or others desiring them.

62. Q. *How long may empty cans be left at the railroad station after arrival?*

A. They must not be left longer than one day. They

should be taken away from the railroad station as soon as possible.

63. Q. *Should can racks be provided for empty cans?*

A. Yes. Can racks are necessary for the purpose of inverting emptly cans in pure air as required by law. Such racks should be large enough to hold all surplus, empty cans which are likely to be on hand at any one time. Said racks are required to be built on the inside of station or can room.

64. Q. *What should be done with any cream held over after a shipment is made?*

A. Weigh, sample, test and record the results on the daily sheet in pounds butterfat as well as pounds cream.

65. Q. *How would you check your work to locate shortage?*

A. Make a composite on the day's work. If it does not check out, have the weighing and testing scales examined.

66. Q. *How much sulphuric acid should be used when testing milk?*

A. About 17.5 cc. is correct.

67. Q. *At what temperature should milk tests be read?*

A. Read milk tests at 130 degrees F.

68. Q. *How should the length of the fat column of milk tests be measured or read?*

A. See illustration on page 25.

69. Q. *State briefly the different steps to be observed in milk testing.*

A. Answer this question by stating the fourteen steps outlined on page 25.

THE STATE AGRICULTURAL COLLEGE
OF COLORADO

The Thirty-Seventh Annual Report

OF

The Colorado Agricultural Experiment Station

FOR THE YEAR 1924

The Colorado Agricultural College

FORT COLLINS, COLORADO

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ALVIN KEZER, A. M. .....Agronomist
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B. O. LONGYEAR, B. S. .....Forestry Investigations
I. E. NEWSOM, B. S., D. V. S. .....Veterinary Pathologist
(1) A. K. PEITERSEN, B. S., M. S., Ph. D. .....Botanist
(2) L. W. DURRELL, Ph. D. .....Botanist
RALPH L. PARSHALL, B. S. .....U. S. Irrig. Eng. Irrigation Investigations
R. E. TRIMBLE, B. S. .....Assist., Irrig. Investigations (Meteorology)
EARL DOUGLASS, M. S. .....Associate in Chemistry
P. K. BLINN, B. S., Rocky Ford .....Alfalfa Investigations
MIRIAM A. PALMER, M. A. .....Delineator and Assistant in Entomology
J. W. ADAMS, B. S., Cheyenne Wells....Assistant in Agronomy, Dry Farming
N. E. GOLDTHWAITE, Ph. D. .....Home Economics Investigations
CHARLES R. JONES. B. S., M. S. .....Associate in Entomology
(3) GEORGE M. LIST, B. S., M. S. .....Associate in Entomology
CHARLES I. BRAY, B. S., M. S. .....Associate in Animal Investigations
E. J. MAYNARD, B. S. A., M. S. .....Associate Animal Husbandman
W. L. BURNETT .....Rodent Investigations
FLOYD CROSS, D. V. M. .....Assistant Veterinary Pathologist
WM. H. FELDMAN, D. V. M. .....Assistant Veterinary Pathologist
J. H. NEWTON, B. S. .....Assistant in Entomology
CAROLINE PRESTON .....Artist in Botany Section
J. L. HOERNER, B. S. .....Assistant in Entomology
J. W. TOBISKA, B. S., M. A. .....Assistant in Chemistry
C. E. VAIL, B. S., M. A. .....Assistant in Chemistry
C. D. LEARN, B. S., M. A. .....Assistant in Botany
DAVID W. ROBERTSON, B. S., M. S. .....Associate in Agronomy
I. G. KINGHORN .....Editor
R. A. McGINTY, B. S., A. M. .....Associate in Horticulture
(4) B. MILDRED BROWN, B. S. .....Assistant in Bacteriology
C. M. TOMPKINS, B.S., M.S. .....Assistant in Horticulture
L. A. MOORHOUSE, B. S. A., M. S. .....Rural Economics
R. T. BURDICK, B. S., M. S. .....Associate in Rural Economics
CHAS. N. SHEPARDSON, B. S., M. S. .....In Charge of Official Testing
H. D. HORTON, B. S. .....Assistant in Agronomy and Horticulture
J. C. WARD, B. S., Rocky Ford .....Soil Chemistry
J. W. DEMING, B. S. A. .....Assistant in Agronomy
H. B. PINGREY, B. S. .....Assistant in AgriculturalEconomics
IDA WRAY FERGUSON, R. N. .....Assistant in Bacteriology
ROSS C. THOMPSON, B. S., ...Assistant in Horticulture

ENGINEERING DIVISION

LD CRAIN, B. M. E., M. M. E. .....Mechanical Engineering
E. B. HOUSE, B. S., (E. E.) M. S. .....Civil Engineering
O. V. ADAMS, B. S., M. S. E. .....Associate in Civil Engineering
G. A. CUMINGS, B. S. .....Assistant in Mechanical Engineering

(1) Died February 23, 1924.
(2) Appointed September 1, 1924.
(3) On leave.
(4) Resigned July 1, 1924.

LETTER OF TRANSMITTAL

To His Excellency, William E. Sweet, Governor of Colorado:

In accordance with the law of Congress establishing Agricultural Experiment Stations, I have the honor to transmit to you, herewith, the Thirty-Seventh Annual Report of the Colorado Agricultural Experiment Station for the Federal fiscal year, July 1, 1923 to June 30, 1924.

The report contains a full financial statement of all receipts and disbursements, and brief summaries of the work done by those in charge of the different sections or departments of the Experiment Station. There is also given a full list of projects upon which work has been done during the year.

C. P. GILLETTE,
Director.

Agricultural Experiment Station
Fort Collins, Colorado.
December 1, 1924.

FINANCIAL REPORT OF THE COLORADO AGRICULTURAL EXPERIMENT STATION FOR THE FISCAL YEAR ENDING JUNE 30, 1924

DR.	Hatch Fund	Adams Fund	State Mill Levy Fund	Special Fund	Pure Seed Fund App'n.	Special App'ns.	Total Funds
Balance, July 1, 1923	.....	.....	$ 10,688.15	$ 9,793.39	$8,470.18		$ 28,951.72
From the Treasurer of the United as per appropriation for the fiscal year ending June 30, 1924, under acts of Congress approved March 2, 1887, (Hatch Fund), and March 16, 1906 (Adams Fund)	$15,000.00	$15,000.00					30,000.00
Other Sources than the United States			103,540.92	33,332.75			136,873.67
Special appropriation for stations at Greeley and Cheyenne Wells						$14,000.00*	14,000.00
	$15,000.00	$15,000.00	$114,229.07	$43,126.14	$8,470.18	$14,000.00	$209,825.39
CR.							
To Salaries	13,894.25	13,994.33	62,444.09	.....	3,930.31	.....	94,262.98
Labor	102.64	51.90	10,781.44	1,288.90	1,510.78	1,223.17	14,958.83
Stationery and office supplies	31.45	.....	1,087.42	112.61	192.17	8.00	1,431.65
Scientific supplies, consumable	140.99	142.75	799.69	3,844.87	108.31	.....	5,036.61
Feeding stuffs	44.79	5.97	2,575.84	5,408.59	.....	.....	8,035.19
Sundry supplies	125.37	22.40	1,427.20	433.41	102.65	74.21	2,185.24
Fertilizers	.....	.....	49.21	.....	.....	....	49.21
Communication service	18.31	.....	456.44	70.67	9.81	0.25	555.48
Travel expenses	111.04	143.65	5,463.79	952.07	574.95	78.30	7,323.80
Transportation of things	.....	.....	881.21	75.25	10.04	6.79	973.29
Publications	2.32	.....	1,486.32	690.75	21.51	.....	2,200.90
Heat, light, water and power	.....	.....	160.99	38.94	.....	.....	199.93
Furniture, furnishings and fixtures	21.25	358.50	1,859.72	1.35	44.20	26.33	2,311.35
Library	8.83	9.91	502.81	50.66	8.00	.....	580.21
Scientific equipment	387.93	270.59	3,461.97	490.26	439.12	.....	5,049.87
Livestock	.....	.....	364.25	8,189.21	.....	.....	8,553.46
Tools, machinery, appliances	6.00	.....	1,488.23	638.78	.....	386.38	2,519.39
Buildings and lands	104.83	.....	6,798.12	1,439.90	50.35	1,172.12) 9,700.00)**	19,265.32
Contingent expenses	.....	.....	482.40	211.00	.....		693.40
Total expenditures	$15,000.00	$15,000.00	$102,571.14	$23,937.22	$7,002.20	$12,675.55	$176,186.11
Balance on hand June 30, 1924	.....	.....	11,657.93	19,188.92	1,467.98	1,324.45	33,639.28
Grand Total	$15,000.00	$15,000.00	$114,229.07	$43,126.14	$8,470.18	$14,000.00	$209,825.39

*Greeley appropriation, $10,000; Cheyenne Wells, $4,000

REPORT OF THE DIRECTOR

To the President:

A short summary report of the activities of the Colorado Agricultural Experiment Station, together with a full financial statement of receipts and disbursements for the Government fiscal year, July 1, 1923, to June 30, 1924, is presented herewith for your information.

It will be noted that the regular income of the Station consisted of $15,000 each, from the Federal funds known as the Hatch Act and Adams Act, respectively, a State levy of 0.0675 of a mill upon all taxable property, which amounts to about $104,000, and a special fund of $20,407.94 which was derived from the sale of livestock, fruits, grains and vegetables used in the investigational work of the year. The special fund was offset by the purchase of livestock, feeds, seeds and labor. The total net budget for the investigations of the year in all departments was $134,128. In this connection should be mentioned two special appropriations for the biennial period, one of $4,000 for improvements at the Cheyenne Wells Station, payable in two annual installments of $2,000 each, and one for the purchase of land equipment for the Greeley Potato Station, in charge of the Federal Bureau of Plant Industry, of $10,000, payable during 1923, making a total of $146,128.

The acquisition of new scientific knowledge must always be expensive, but it is usually of great value when once obtained. It would seem a small matter to work out a method by which the wheat or corn crop of the State might be increased by only one bushel per acre, and yet, such an increase to either of these crops for one year would be sufficient to supply the full Experiment Station budget for at least five years. Or put it in another way; the entire annual mill levy for the Experiment Station would amount to a per capita tax in Colorado of only 11 cents. As the rural population pays about one-half the total State tax, the Experiment Station costs the farmers of the State an average of about $1.00 each per year. The writer believes the Experiment Station returns a good annual dividend to the farmers of the State on the money they have invested in it, besides being of considerable value to surrounding states and to the Agricultural College as an educational factor.

When the average annual per capita expense for candy, tobacco, gum and cosmetics, and other useless or worse than useless luxuries, exceeds $50.00, it does not seem that an excessive amount is being devoted to investigational work for the improvement of our agriculture which must be the chief basis for our material prosperity.

There are many lines of research receiving meager support and many new lines that should be undertaken, but we are endeavoring to do as much as possible on the more important problems with the funds available and hope that, from time to time, the State may see fit to increase its budget for the support of the investigational work of the Agricultural Experiment Station.



DR. ARNE K. PEITERSEN

The Station personnel has not changed much during the year. One department head and three other regular workers have left the Station for one reason or another, and one department head and two other workers have been added. At the present time there are 13 employees giving full time and 33 giving part time to the investigational work. The writer believes better results will be obtained when it is possible to have a larger proportion of the workers giving full time to research.

Dr. Arne K. Peitersen, head of the Department of Botany of the Colorado Agricultural College and also in charge of the investigational work in botany for the Experiment Station, died suddenly in Grand Junction, Colorado, February 23, 1924, while in the performance of his duties as botanist in charge of the State Seed Laboratory.

Arne K. Peitersen was born at Elkhorn, Iowa, March 9, 1884, and graduated from the University of Nebraska in 1911 with the degree of bachelor of arts. The year following he received the master of arts degree from the same institution, doing his major work in botany, and he was also elected to membership in the honorary society of Sigma Xi. In the same year, 1912, he was elected to be head of the Department of Botany in the University of Vermont, and in 1916 received his Doctor of Philosophy degree from that institution. The major work for this degree was upon "A Study and Revision of the genus rebus in North America." Dr. Peitersen was called early in 1920 to the chair of Botany at the Colorado Agricultural College, where he entered upon his duties June 1 of that year. As head of this department he was also in charge of the investigational work in Botany for the Experiment Station, and of the Colorado Pure Seed Laboratory established at the Agricultural College. In his direction of the work of the Seed Laboratory he did much to raise the standard of farm and garden seeds in the State and, consequently, the products of farm and garden.

Dr. Peitersen was a man who had a keen appreciation of honest, thorough-going scientific work, was himself a scientific investigator of high ability, and possessed a personality that caused him to be loved by all who were associated with him. His untimely death was a serious loss to the investigational work of the Colorado Agricultural Experiment Station, and was felt as a personal loss by all who were acquainted with him. His picture is shown on the opposite page.

The work on niter control, co-operated in by the sections of Agronomy and Bacteriology, and the American Beet Sugar Company at Rocky Ford, has made good progress again this year. Much additional information has been obtained from chemical analyses of the soils, all of which are in harmony with the conclusions formerly drawn by workers in this Station concerning the development and nature of our niter problems in the State.

Following is a list of the projects that are approved for the investigations of the different sections of the Experiment Station at the present time:

AGRICULTURAL DIVISION

Agronomy Section

Relation of Soil Moisture, Structural Development and Acre Yields in Small Grains. Adams and State funds.

Correlation of Characters in Grain. Hatch and State funds.

Methods of Selection Breeding. State funds.

High-Altitude Crops. State funds.

Plains Crops and Management. State funds.

Arkansas Valley Nitre Control. (In co-operation with Bacteriology and Irrigation Investigations). State funds.

Improved Seed. State funds.

Animal Investigations Section

Acre Value of Pasture for Daily Cows. State mill levy.

Ration and Experiments with Steers. State mill levy.

Ration for Fattening Lambs. State mill levy.

Range Improvement. State mill levy.

Winter Maintenance of Breeding Ewes. State mill levy.

Summer-Fallow Experiment at Akron, Colo. State mill levy.

Supervision in Dairy-Cow Records. State mill levy.

Incubation Tests. State mill levy.

Corn Field Lamb Feeding. State mill levy.

Death Losses among Lambs in Feedlots in San Luis Valley. State mill levy.

Bacteriology Section

Heat-Resisting Bacteria in Fresh and Canned Vegetables. Adams fund.

Value of Certain Carbon Compounds as a Source of Energy for Azotobacter. Adams fund.

Arkansas Valley Nitre Investigation. State mill levy. (In co-operation with Agronomy Section).

Bacterial Disease of the Wragg Cherry. Hatch Fund.

Botany Section

Hard Seed in Alfalfa. State mill levy.

Range Improvement (In co-operation with Animal Investigations). State mill levy.

Plant-Disease Survey. State mill levy.

Root Disease of Alfalfa. Adams fund.

Chemistry Section

Nitre in Colorado Soils, its Occurrence, Formation and Effects upon Vegetation. Adams fund.

(a) Relation of Nitrates to Potato Diseases in the Greeley District, Colorado.

Entomology Section

Plant-Louse Investigations. Adams fund.

Ants of Colorado in their Relation to Plant Lice. Hatch and State mill levy.

Codling-Moth Control. Hatch and State mill levy.
Grasshopper Control. State mill levy.
General Insect Investigations. State mill levy.
Alfalfa Nematode Studies. State mill levy.

Economics and Sociology

Marketing Investigations, in co-operation with the Colorado Division of Markets, Denver, Colorado. State mill levy.

Settler's Progress Study, in co-operation with the Division of Land Economics and the Office of Farm Management and Farm Economics, U. S. Dept. of Agriculture. State mill levy.

Cost of Producing Beef Cattle on the Range, in co-operation with Cost of Production and Farm Management Division, U. S. Dept. of Agriculture. State mill levy.

Farm Organization and Costs on Farms in the Greeley Area in co-operation with Division of Farm Management and Farm Economics, U. S. Dept. of Agriculture. State mill levy.

Rural Life Studies, in co-operation with the Rural life Section of the Bureau of Agr. Economics, U. S. Dept. of Agriculture. State mill levy.

Forestry Section

Studies in the Decay of Wood. State mill levy.

Home Economics Section

Cooking Quality of Colorado Potatoes. State mill levy.

A Study of the Bread-making Qualities of Colorado Flours. State mill levy.

Principles of Making Fruit Jellies. State mill levy.

Horticultural Section

Potato Investigations. State mill levy.
Seed-Potato Growing in High Altitudes. State mill levy.
Hardy Tree Fruits for High Altitudes. State mill levy.
Tomato Variety Tests. State mill levy.
Head Lettuce in High Altitudes. State mill levy.

Irrigation Investigations Section

The Venturi Flume. Adams fund.
Evaporation Experiment. Hatch fund.
Meteorology. State mill levy.
Measurement of Water as Applied to Irrigation. Hatch fund.
Arkansas Valley Nitre Investigations. State mill levy.

Pathology Section

Sheep Losses in Feedlots. Hatch fund.
Contagious Abortion. State mill levy and Hatch funds.

Veterinary Section

Animal Diseases. State mill levy.

ENGINEERING DIVISION

Civil Engineering Section

Road Materials of Colorado. State mill levy.

Mechanical Engineering Section

Treatment of Alkali and other Waters for Domestic Use. State mill levy.

Testing of Lubricating Oils. State mill levy.

The Humidifying of Air in Buildings. State mill levy.

Brief reports of the heads of sections are given on the following pages.

Respectfully submtted,
C. P. GILLETTE, Director.

REPORT OF THE AGRONOMIST

To the Director:

I am substituting herewith my report of the Agronomy Section of the Experiment Station for the Federal fiscal year, July 1, 1923 to June 30, 1924. The work of the Agronomy Section for the year was carried out with the following personnel:

At Fort Collins, Alvin Kezer, chief; D. W. Robertson, associate; G. Warren Deming, assistant; Asa Barnhart, laborer, with the further assistance of student help hired by the hour.

At Cheyenne Wells, Mr. J. W. Adams, superintendent;; Irvin Rahe, Clyde O. Gregg, F. A. Wood, laborers.

At Rocky Ford, P. K. Blinn, superintendent; Justus C. Ward, chemist; and R. S. Harrison, laborer.

At Fort Lewis, Harrison D. Horton, assistant.

Work was conducted at Akron under a co-operative arrangement with the office of Dry Land Agriculture, helped out by visits and special trips of workers to take notes on products and crops in the course of their development.

At the Fort Collins plant the following projects were actively under way:

Critical Periods in the life history of plants for the need of moisture and physiological effects resulting from the application at those critical periods or the withholding of water from the plant at those critical periods. This project is an Adams fund project designed to discover the fundamental facts in the life history of small-grain crops, especially with respect to their needs for water. In carrying out this project two methods of attack have been followed: First: field plats one five-hundredth of an acre in size provided with moveable covers to prevent precipitation getting on the plats and with suitable drainage at the side to quickly remove drainage from the plat covers, and, second, potometers grown in the same field with similar cover protection. Up to the present time we have not been able to get

results in the potometers comparable with field development of crops. What the trouble is we do not know. We are attempting to find out, but we do know that the crops in the potometers do not develop in the same way as the crops develop in the field. In the case of the small field plats under removable covers, however, the plats do behave comparable to field conditions.

As a matter of practical administration and expense, we have been obliged to confine our investigations to one crop at a time. Accordingly, spring wheat has been used to work out the factors for that crop. We now have four years' consecutive results under the present plan of handling the work. These data show positive results. Only a brief statement of the trend of these results will be given here since manuscripts are nearly completed for publishing the results up to date.

It may not be out of the way to mention the fact that from the standpoint of yield and quality of the crop, if there is water enough in the soil to start the crop and keep it growing fairly well until the heading period, an application of water just prior to heading gives the greatest results in yield and quality of the grain. Later applications of water do little good if there is sufficient water applied at this period. Water applied at an early period and withheld later affects the shape, size and development of the wheat kernel. Since the details of these physical and physiologic changes are set forth in a separate manuscript now in preparation this need not be discussed in full in this annual report.

In addition to the Critical-Period project, we are carrying a general project known as Improved Seed. Under this project we are attempting some of the more practical phases of agronomic work. We are breeding new crops, testing them out to get their values as compared to existing crops; we are bringing in new varieties from the outside, testing them; we are increasing seed of the new varieties which prove their worth, whether bred up by ourselves or imported from the outside; we are purifying existing standard and proved varieties and distributing seed of all of these various operations to farmers.

We distributed in the spring of 1924, two tons of Colsess barley, a new variety which the Station produced by crossing Coast (California Feed) and Success. Coast is a high-yielding, vigorous barley, but it has long and coarse, barbed beards, which render it unfit for hay and often make the straw unfit for feeding purposes because the beards are apt to cause sore mouth when eaten by stock. The new variety, Colsess, in a six-year test at Fort Collins and at Fort Lewis yields practically as well as the best Coast and it has no beards. The beardless character makes this new barley available for use in our mountain districts and elsewhere as a grain, because it yields high, as a mixture in pea-grain mixtures, as a grain hay, or it may be harvested, thrashed and the straw fed without danger to animals. The variety is very tenacious of the berry so that shattering of the kernels in the field is reduced to a minimum. These qualities combined with a good yield of stiff straw make this barley a very decided addition to the barley

crop. It will very greatly increase the feed grain and barley hay possibilities of our mountain districts.

We are also conducting a continuation of the experiments in determining the best methods of planting and handling different crops in our experimental work, whether in breeding or crop or soil tests. The necessity for this work is seen when we realize that crops like corn or rye are cross fertilized abundantly and must be segregated if their strains are to be kept pure. Occasional crossing will take place with oats and wheat so that a moderate amount of segregation is necessary with these crops. Recognition must be kept in mind of the different physical behaviors of different crops in the field. Methods of handling and planting must be such as to make mechanical mixture impossible.

Rotations are also being given attention not only from the standpoint of improving products from the land but also from the standpoint of finding the best crop sequence. We realize thoroly that crops leave a residual effect. In some cases this residual effect is beneficial to the succeeding crop and in some cases injurious or retarding to the succeeding crop. In other words we are attempting to find the order of sequence which will give the best results so as to take advantage of these residual effects rather than to be hampered or have the yields reduced by such residual effects.

At Cheyenne Wells we doubled the number of forage test plats making something over seventy plats in all in addition to increasing the plantings for annual pasture experiments on a field scale. The appropriation has been, and is being used, to improve the fences, to add four new silos to our building equipment, to build an addition to the barn covering the silos, to build a new chicken house and to start work on two other buildings. Briefly summarized, the appropriation was used to put the physical plant in shape so that experimental work could be better carried on, and, second, to very greatly increase the amount of plat work with forage and pasture crops in an attempt to help solve the most insistent dry-land problems of the region.

At Rocky Ford the co-operative work between the sections of Agronomy and Bacteriology in the attempt to find means of control of the nitre problem at that point has been continued. The personnel in the work is the same as the previous year. Nineteen twenty-two was one of the driest years in the history of the Station. The year 1923 was the wettest year ever recorded since weather records have been kept at Rocky Ford. The 1923 precipitation broke the previous high record by over five inches. Our attempt at solving the excessive production of nitrates has been along two lines: First by the use of agricultural methods and rotations, and, second, by the application of chemicals. The two years' results which are complete, namely 1922 and 1923, show that the order of production of nitrates follows the same law. Briefly stated, nitrates are high where the land is cultivated and low when the land is in an uncultivated crop, such as alfalfa, clover, sweet clover, or in pasture or small grains. There are diferences in the production of nitrates in different cultivated crops but the general

law holds that the production is high where the crop is cultivated in the course of its production. The general scheme of agricultural control is to devise a rotation to take advantage of these facts. Chemical treatment may be of assistance, but agricultural treatment thru rotations is sound because good rotations will result in better agricultural practice. Certain types of plats representing different treatments were sampled once a month to a depth of six feet, so that we have a picture of nitrate formation and movement in the soil to a depth of six feet.

In addition to the nitrate work at Rocky Ford, we have been spending considerable effort in the attempt to exterminate a bad bindweed infestation. We have had considerable success in that attempt. Thoro plowing and clean cultivation for two years will completely eradicate the bind weed. But thoro cultivation means the use of knives or a cultivator using sweeps so as to cut the entire surface, cutting off the bindweeds from one to two inches beneath the surface. This cultivation has to be done frequently enough to prevent any growth of tops. Sometimes in the middle of the summer the frequency has to be as often as each four days. The problem seems to be entirely one of controlling any growth. If the growth is entirely stopped the root will be starved in time. In fact, the process, if carried out with sufficient thoroness and frequency, will nearly kill out the patches in one year. However, such thoro work cannot be done and have a crop on the land. This intensive fighting can only be done with a fallow. By growing cultivated crops such as beets or beans, which permit of continuous cultivation or hoeing, it is possible to approximate the fallow and yet grow something of a crop.

The alfalfa work at Rocky Ford, due to the pressure of the nitrate work, is being held largely in abeyance. We are attempting to hold seed stocks of our superior strains so that we can go forward with that work when the nitrate is completed. In our alfalfa work we found out definitely that we can breed new and superior strains. We have done a great good to the State in the determining of the types adapted. Our greatest difficulty has been to solve the problem of consistent seed production. Our supply of land and our means of personnel are not sufficient to push the the alfalfa investigation and the nitrate investigation at the same time. Accordingly, we are trying to hold seed stock so as to take up the alfalfa problem.

We want to attempt to solve the seed production question and the factors controlling the same.

At Fort Lewis investigations are on high-altitude or mountain agriculture. Our first attempts at Fort Lewis are to find adapted crops and methods of handling those crops. With that end in mind we have carried out variety tests of oats, wheat and barley and some forage crops to determine the things most immediately needed in mountain agriculture. We have carried on these variety tests with peas, wheat, oats and barley. We have done minor work with corn and forage crops other than those mentioned. We are giving the

largest part of our attention to those crops which give the greatest promise in mountain agriculture at rather high altitudes.

Approximately two-thirds of the area of Colorado is more or less effected by mountain agriculture, high altitude in nature. Approximately one-third of Colorado lies east of the mountains on our high plains. The remaining two thirds consists of high plateaus, table lands, mesas, and valley lands. Much of the area is not adapted to farming other than grazing, but that which is adapted is capable of supporting a considerable agriculture. We are able to center our attempt to solve the cropping and soil problems of these high altitudes at Fort Lewis and supplement the tests with plantings arranged with farmers in North Park, Middle Park, South Park and the northwest.

There are many problems confronting the Agronomist which need definite experimentation. Our Great Plains and those mountain regions capable of dry farming constitute a distinct phase of investigation, which should be given much more attention than we have been able to give in the past. There are about 66,000,000 acres in Colorado. Approximately 22,000,000, or one-third of the State, lies east of the mountains. Perhaps 2,000,000 to 2,500,000 acres of this region is irrigated, leaving between 8,000,000 and 9,000,000 acres of land now under cultivation, which is cultivated by dry-land methods. Much of this land is going to be utilized. How to utilize this land is a problem of soil and crop management. We are doing something co-operatively to help solve this problem thru the work at Akron. We are doing what our means permit at Cheyenne Wells, but the need of the region is sufficiently large to justify more financial support and a heavier personnel for this particular region. We know considerable that has not yet been put into practice, but we need to be getting new facts to keep up with and ahead of the agriculture of that region.

High altitude, or mountain agriculture, needs more agronomic investigations. We are pushing the altitudes at which crops may be grown to higher reaches. We have learned a great deal of the fundamental cropping problems but there is much yet to be learned.

Our work in the Arkansas Valley with soil problems indicates that there are other features besides those under investigation that need much study. Most of the soils are rich in fertility. But that fertility in poorly balanced. The best method of balancing the fertility is not known, but higher productivity with desired quality is essential.

Respectfully submitted,

ALVIN KEZER,
Agronomist.

REPORT OF THE ANIMAL HUSBANDMAN

To the Director:

Following is a report upon the various projects carried by this section:

Ration Experiments With Steers—E. J. Maynard and Geo. E. Morton.

This year's work was the close of a three-year series, comparing, principally, rations containing corn silage and sunflower silage with the standard wet-pulp ration. We have secured sufficient data so that the sunflower-silage phase of the work will be discontinued. Dried pulp was also tested in comparison with grain in these silage rations.

Ration For Fattening Lambs.—E. J. Maynard.

A number of different rations were compared, the more interesting comparisons being the grain-replacement value of dried pulp; the feeding of beet molasses in a self-feeder; the value of oats and linseed meal in rations where alfalfa hay is used.

Corn-Field Lamb Feeding.—E. J. Maynard.

A test comparing lambing-off corn in the field with dry-lot feeding.

Death Losses Among Lambs in Feedlots in San Luis Valley.—E. J. Maynard.

A series of investigations was carried on by the Veterinary Pathology Section of the Station with a view to finding the cause of death losses. They carried their investigations to a point where they were satisfied it was a disease condition connected with rations fed or methods of feeding, so our present investigations are being carried on to find whether the death losses can be reduced by means of addition of other feed stuffs to the rations in connection with lambing-off field peas.

Range Improvement.—E. J. Maynard.

This investigation necessarily covers a series of years with no definite time limit. At present, its scope comprises three different methods of handling cattle on the range. The work is being done in co-operation with the Botanical Section.

1. Ordinary early grazing is practiced, cattle being turned out as soon as there is grass in the spring.
2. Grazing is delayed until vegetative maturity of the grasses.
3. Rotation grazing with area divided in two parts, one-half being grazed off the fore part of the season; the other half, after seeding of the grasses.

Summer Fallow Experiment with Sheep at Akron, Colorado.—Geo. E. Morton and E. J. Maynard.

An investigation designed to cover a considerable length of time with a view to discovering (over a series of years so as to include all rainfall conditions) the advisability of maintaining sheep upon dry-land farms for the purpose of grazing off weed growth on summer fallow and thereby reducing the labor required for summer tillage; also, to find the number of sheep which can be carried over a series of years on a given acreage of summer fallow and supplementary pasture of native grasses.

Winter Maintenance of Ewes.—Chas. I. Bray.

An investigation into methods of cheaply maintaining winter ewes. The experiment of the past year was with farm ewes.

Acre Value of Irrigated Pasture.— Geo. E. Morton.

An investigation into the carrying capacity and value of irrigated pasture for dairy cows.

Incubation Tests.—O. C. Ufford.

An investigation of moisture and aeration conditions required for hatching hen's eggs at this altitude.

Advanced Registry Testing.—Chas. N. Shepardson.

The projects for the coming year are the same as for last year, with changes in details of the investigations.

In steer experiments, calves will be used this year instead of yearlings, as in the series just closing. Rations for the calves will cover the comparative values of corn fodder, corn silage, corn and soy-bean silage, potatoes, and potato silage, with supplementary grain rations.

In the ration experiments with lambs, the following feed stuffs will be used to determine their value as partial supplements to corn: Dried Beet Pulp, Corn Silage, Corn and Soy-Bean Silage, Potato Silage, Cull Potatoes, Wet Pulp. One lot will be self-fed on the ground mixture of corn, dried beet pulp and alfalfa.

The range-management experiment will be continued with cows instead of steers.

Winter maintenance-of-ewes investigation will be carried on with range ewes instead of farm ewes, although the feeding will be done under farm conditions.

Other investigations will be carried o nthe same lines as last year.

The results from our ration experiments with steers and fattening lambs, particularly, are going into use among the feeders of Colorado, especially in this section and the Platte Valley. Lamb Feeders' Day and Steer Feeders' Day held at the close of the ration experiments, bring to the campus, for discussion of investigational results, the largest bodies of bonafide stockmen and farmers that come to the College for any meetings. This enables us to get our results immediately in use and also bring a closer connection between the actual feeders and the Experiment Station.

Respectfully yours,

GEO. E. MORTON,
Animal Husbandman.

REPORT OF THE BACTERIOLOGIST

To the Director:

I have the honor to submit herewith the annual report of the Bacteriological Section of the Experiment Station for the fiscal year ending June 30, 1924:

As our investigational work progresses, we are coming to realize more and more the wisdom of concentrating our efforts on a few problems. Two lines of work have been supported by the Adams fund, one by the Hatch fund, and one by State funds. Marked progress has been made in three of these, while the fourth has been more or less quiescent, because of the lack of time necessary to pursue it. In addition to this, we have given some time to minor problems demanding immediate consideration and to laboratory service for other sections of the Experiment Station. A great deal of material calling for laboratory examination is referred to this section through correspondence, and while the individual specimen may require but little attention, the examination of the aggregate demands an appreciable amount of time. Service of this character is legitimate and should receive careful and prompt consideration; however, the fact should not be overlooked that it takes time from investigational work, and due allowance should be made for this.

Adams Fund Projects

1. Vegetable Spoilage:

When this project was drafted originally, it was intended to make it a study of the different agencies which cause spoilage in canned food products, but since its inception it has been modified to include certain phases of *botulinus* poisoning.

The investigation of the year may be divided into two parts: The first has been carried on in co-operation with Miss Sheridan of the Extension Department, and has dealt with the lag encountered in canning different vegetables by the wash-boiler method, at altitudes of 4000, 5000, 6000, and 7000 feet. In a general way, we have found that the lag varies inversely as the altitude and that it ranges from eighteen minutes to one hour and fifty-three minutes, depending upon the kind of vegetable that is being processed.

The second part has been a study of the occurrence of *Bacillus botulinus* in Colorado soils, collected from widely separated localities and representing both virgin and cultivated areas. The results thus far indicate that approximately 11 percent of the samples examined contain the germs responsible for *botulinus* poisoning. Both virgin and cultivated soils have reacted positively.

2. Aztobacter Energy Studies:

The work of previous years on this project had dealt with the relation of green manures and sulphur to the fixation of atmospheric nitrogen by *Azotobacter* and other non-symbiotic soil organisms. The results of this investigation pointed to the desirability of undertaking

a study of the relation of green manures and sulphur to soil acidity as a limiting factor to nitrogen fixation.

To this end, some preliminary work has been carried on in the determination of the hydrogen ion concentration of soils to which sulphur has been applied, but lack of time has prevented us from making any material progress. Recently our laboratory has been equipped with suitable apparatus for making hydrogen ion determinations electrometrically, which will enable us to handle many more samples in a given time than formerly by the colorimetric method.

Hatch Fund Project

1. Bacterial Disease of the Wragg Cherry:

The completion of this project has been delayed for several years because of our inability to produce the disease in cherries by inoculations with pure cultures of the micro-organism thought to be responsible for the trouble.

By employing a culture, isolated in 1923, which had been grown in laboratory media for nearly one year, we succeeded in the spring of 1924 in producing 100 percent infections in green cherries under field conditions. The inoculations in the present instance were made earlier in the season than previously and before any natural infections were visible.

At this early date, the natural acidity of the green cherries was found to be relatively low, which increased quite appreciably as the fruit developed. This change in acidity may explain our failure to secure successful infections in former years, as our inoculations were probably made after the cherries had become too acid to permit the normal progress of the disease.

All that remains to complete this investigation is a little further cultural work upon the castral organisms which appears to be similar to, if not identical with, *Pseudomonas pruni.*

State Fund Project

1. Rocky Ford Niter (Sections of Agronomy and Bacteriology) Co-operation

Owing to the heavy rainfall in 1923, the accumulation of soil nitrates did not reach as high a point as in 1922, but the same general relation to crops and methods of handling the soil maintained as in former years. The nitrates under alfalfa, clovers, and small grains remained consistently low, while they were uniformly high under cultivated crops, notably onions and cantaloupes.

Chemical treatments in the form of applications of sulphur, alum, and ammonium sulphate were made to different fallow plots to determine the effect upon nitrate production. Of the three, sulphur was the only one that showed any decided action. Here nitrate formation was so retarded that only a trace was present by the close of the season of 1923.

Parallel nitrate and chloride determinations, made upon all of the samples, have failed to show any correlation between the two salts.

Because of the badly diseased condition of the vine crops on our experimental plots in past years, it has been difficult to say how much of the poor quality of the melons should be attributed to excessive nitrates and how much to disease. This year, we are endeavoring to control the various diseases by spraying with Bordeaux mixture.

A brief report by Mr. Ward, chemist in charge of the Rocky Ford laboratory, follows:

"To the Director:

"During the past year the Colorado experiment Station Laboratory at Rocky Ford, Colorado, has advanced its investigational work under the joint supervision of the Agronomy and Bacteriological Sections of the Experiment Station.

Analyses of twenty-eight hundred and two silos were made, both the nitro nitrogen and the chlorine values being determined. And since the nitric nitrogen values are secured by duplicate analyses, a total of eight thousand four hundred and six separate determinations was made.

Soil samples were taken from the plots on the Station Farm, from selected plots on the American Beet Sugar Company's experimental farm, and from seven privately owned farms in the vicinity of Rocky Ford. The methods of sampling were the same as have been followed in previous years; namely, the surface samples were taken to the depth of four inches every two weeks from all fields studied, while deep samples to the depth of six feet were taken from selected plots each month.

The findings of the year fully support previous results, so that justification is had for the extension of the investigation along certain well-defined lines.

In the light of the results so far obtained, it would seem profitable to include a more definite investigation of proper rotational systems in the coming year's work. Also, it would seem advisable to follow the effects of the application of commercial fertilizers upon nitrogen fixation wherever the opportunity offers.

A continuation of the established investigations, as well as the addition of the two mentioned, is contemplated for the coming year."

Miscellaneous Investigations

1. Alfalfa Wilt or Root Rot:

A very serious wilt or root rot of alfalfa, resulting in the destruction of hundreds of acres of alfalfa, appeared in an aggravated form in the spring of 1924. The plants stop growing, wilt, dry up green, finally bleach and die. An examination of the root shows the crown to be badly decayed while the lower part may be perfectly sound. In a few cases a slimy exudate was observed issuing from the brown vascular bundles of the roots, from which bacteria have been isolated.

The disease was general over the State, but caused greater losses in some parts than in others. A similar disease has been reported in previous years, but not with the present severity.

The exact cause remains as yet undetermined, but it is probably of either bacterial or fungous origin.

2. Cantaloupe Vinegar:

The utilization of waste cantaloupes from the seed-producing sections of the State for vinegar has been given some consideration. Cantaloupes contain between 6.5 and 7 percent of fermentable sugar, which

could be converted into alcohol and vinegar at a relatively small expense, providing the finished product possessed no objectionable flavor.

3. Ice Cream:

A rather interesting case of bitter ice cream was referred to us for investigation by a Colorado ice-cream factory. The bitter flavor was found to be due to a bacterium which produced spores that resisted the heat employed in the pasteurization of the ice-cream mixture.

4. Vinegar Cultures:

Pure cultures for making vinegar are still being supplied by the Bacteriological Laboratory. Requests for these are by no means confined to Colorado, but are received from all over the United States and occasionally from foreign countries.

5. Seed Disinfection

Because of the prevalence of diseases on the vine crops in the Arkansas Valley, there has been considerable agitation among both growers and seedsmen over the necessity and value of disinfecting their seed. The method recommended consisted of treating the seed for five minutes with a 1-1000 solution of mercuric chloride. This appears to be efficient so far as disinfection is concerned, but there was some question about the effect of the treatment on germination.

To determine this, we subjected cantaloupe, cucumber and honeydew seeds to the prescribed treatment. Our results indicated that seeds which possessed a high initial germination were practically unaffected, while those with a relatively poor germination in the beginning, were damaged appreciably.

6. Water Supplies:

Chemical and bacteriological examinations have been made of a large number of farm well-waters. This consists as a rule of a qualitative test only, designed to give a general idea of the suitability of the water for domestic, livestock and irrigating purposes.

In this connection, it may be mentioned that the sanitary condition of the water in the swimming pool of the Women's Club is checked regularly by our analyses at stated intervals.

Projects for 1924-1925

The projects for the coming year will be continuations of the present ones, with the probable addition of one relating to the Alfalfa Wilt or Root Rot.

I regret to report the resignation of Miss Mildred Brown, effective July first, who has assisted me so faithfully during the past three years. Miss Brown will be succeeded by Miss Ida Wray Ferguson, as assistant Bacteriologist.

This report would be incomplete without a word of appreciation to the Director of the Experiment Station for his most friendly cooperation and generous support in all of our investigations.

Respectfully submitted,
WALTER G. SACKETT,
Bacteriologist.

REPORT OF THE BOTANIST

To the Director:

The activities of the Botanical Section for the past fiscal year are herewith submitted.

On September 1, 1924, the writer, formerly assistant chief in Plant Pathology, Iowa Agricultural Experiment Station, assumed the duties of the head of the Botanical Department, Colorado Agricultural College.

The following projects have been carried on during the year:

Range Improvement

This project has been carried along the course outlined. Special studies made of quadrats on the Experiment Station farm and at Akron indicate deferred grazing will be of material benefit in native pastures. Such deferred grazing, one year in three, will allow natural reseeding of the native grasses and perpetuation of the forage. The continuous croppings of certain of the native grasses completely kills them out and they become displaced by worthless grasses and weeds. A preliminary paper is in progress on this project.

Hard Seed in Alfalfa

This project has been in immediate charge of Miss Anna M. Lute, Station seed analyst, and certain completed phases of the project are now being prepared for publication. A summary of the findings to be discussed are as follows:

1. The average hard seed percentage for Colorado-grown alfalfa seed is approximately 22 percent each year.
2. Various lots of seed from different localities containing different percentages of "hard seed" planted at the same time, in the same locality, produce the same percentage of "hard seed" at harvest.
3. The percentage of hard seed found in machine-threshed seed from a field in different years varies greatly.
4. There is much more "hard seed" in hand-threshed than in machine-threshed seed.
5. There is great variation in hand-threshed seeds from individual plants in the same field.
6. Seed harvested when slightly immature has a lower germination and a slightly higher "hard seed" content than mature seed.
7. For a given sample, repeated tests show that the percentage of germination and of "hard seed" is constant within the accepted tolerance.
8. The rate of deterioration in germination due to old age is extremely variable.
9. "Hard seed" practically disappears from alfalfa seed after 11 years storage.
10. One-half or more of "hard seed" disappears after three years storage.

11. At least some of these "hard seed" germinate as early as the third year of storage.

12. "Hard seed" of alfalfa kept under good storage conditions germinates more than 70 percent when three years old.

The seed analysis of the laboratory and inspection work has been carried on satisfactorily, and has received good support from both farmers and seedsmen throughout the State. This was particularly reflected at the State seed trade conference recently held here in the seed laboratory.

Plant Disease Survey

This project has been continued and the usual reports made. Due to comparatively low rainfall, plants have been quite free of diseases this past season. The discovery of the alfalfa nematode in Colorado this year was occasion for great alarm. Careful survey of the State, however, proved its distribution and injury quite limited.

Other diseases as root rot in alfalfa, celery rot and stinking smut called for attention this season and suggested investigations now in progress.

Respectfully submitted,
L. W. DURRELL
Botanist.

REPORT OF THE CHEMIST

To the Director:

The Chemistry Section of the Station has engaged itself during the past year very largely with work connected with the experiments carried on at Greeley in conjunction with the pathologist of the Bureau of Plant Industry of the United States Department of Agriculture. This work is not yet completed. There remains a considerable amount to be done, arising from field observations in this connection. These observations emphasize the views that we have expressed repeatedly in the beneficial effects of green manuring and rotation as corrective measures in the case of the nitre question, and give an irrefutable explanation for the inconclusive character of the results obtained in our Greeley series of experiments. These results are much more satisfactory than we had any reason to expect, which appears very conclusively from the observations first made by Prof. Whipple at Delta, who was kind enough to call our attention to two cases in particular in which two different growers had planted potatoes after potatoes, or other cultivated crops along side of land that had been in alfalfa for one or two years—two years, I think, in both cases. The sections of land that had been in potatoes the previous year developed nitrates on a large scale, while the land that had been in alfalfa did not develop them to any unusual extent. The yield on the niter land in one case was 20 sacks (estimated) against 75 sacks after the alfalfa. In the other case, there was no crop on the niter land and 140 sacks to the acre after alfalfa.

We are continuing work on these lines to round out our Greeley experiments whose value has been greatly enhanced by this season's observations in the field.

This season's field work has emphasized the importance of this class of work in the most striking manner imaginable; not that its value has ever been doubted but that it has been demonstrated with unusual force by this season's experience.

The conditions obtaining in our orchards have again come up for consideration from our standpoint. These conditions are, in large sections, very bad indeed, with the promise of unwished-for issues. In fact, they are already so bad in some sections that the issue is no longer in doubt. The abundance and persistency of the codling moth, which renders excessive and expensive spraying indispensable, the general presence of the so-called alkali salts in our soils, and, in many places the occurrence of marl and gypsum, which, either owing to the action of lime alone or to its content of arsenic, is proving exceedingly deleterious in many instances.

The Chemistry Section has prosecuted this subject about as far as it can prosecute it with its present facilities. The questions involved are too big, and from this on we can only repeat our former observations. This does not deny that there are probably some details, perhaps many of them, that might be worth solving, but the main features of the problems involved, so far as the chemist is concerned, have been canvassed—in fact, were for the most part canvassed 17 years ago; but subsequent observations have made it amply worth while to extend the presentation of the whole subject.

We have published but one bulletin during the current year. This presented the work of the year 1920 on the Greeley potato problem. The report on the work of 1921, 22, 23 and 1924 will not be made until the work is completed and will be presented as a single bulletin.

There is some accumulated material pertaining to the condition of our orchards which I intend to gather together and present as a short bulletin early in the next year. I deem this advisable as a means of putting our observations on record. The fourteen years that have elapsed since Bulletin 157 was published have brought with them many changes, and it is to give a brief account of the conditions now prevailing that I propose to present a new bulletin and not republish bulletins 131 and 157. The facts then given are still true, but other phases now claim greater attention than they claimed at that time.

There has been published one scientific article by the section during the year. This was entitled "The Relation of Color and Composition to Luminescence in Calcites." It appeared in the Proceedings of the Colorado Scientific Society.

Respectfully submitted,

WM. P. HEADDEN.

Chief of Chemistry Section.

REPORT OF ECONOMICS AND SOCIOLOGY SECTION

To the Director:

This department has continued its studies in the development of the five projects which were outlined in the annual Experiment Station report for the year 1923. The list of projects as reported at that time were as follows:

1. Marketing Investigations; in co-operation with the Colorado Division of Markets, State House, Denver, Colorado.
2. Settlers' Progress Study; in co-operation with the Division of Land Economics and the Office of Farm Management and Farm Economics, U. S. Department of Agriculture.
3. Cost of Producing Beef Cattle on the Range; in co-operation with Cost of Production and Farm Management Division, U. S. Department of Agriculture.
4. Detailed Farm Accounting and Farm Organization Analysis; in co-operation with 25 farmers in the Greeley district and the Division of Farm Management and Farm Economics, U. S. Department of Agriculture.
5. Rural-Life Studies. The investigations to which reference was made last year have been continued and co-operative work was begun with the National Child Welfare Bureau for the purpose of securing information with respect to child-labor conditions in the sugar-beet districts of Colorado.

Report of Progress on Project No. 1.

The causes that bring about carlot rejections of fruit and vegetables constituted the major inquiry in this co-operative enterprise. Representative records were secured from dealers engaged in handling these products. The statistical records which were assembled have been summarized, in part, and a report giving the results of this investigation will be made available in the near future. In view of the fact that the conditions which obtain thruout a given marketing season are often entirely different from the conditions which prevail the succeeding year, it has appeared to be desirable to continue this investigation for two or more seasons. Some observations were also made in regard to results secured in holding head lettuce in cold storage under different conditions. A report giving some suggestions relative to these observations and findings has been prepared and submitted for publication.

Report of Progress on Project No. 2.

The field work for the Settlers' Progress Study was completed in August, 1923. The Division of Land Economics, U. S. Department of Agriculture, carried thru the statistical work on these records and a preliminary report under the title "Dry Farming in Eastern Colorado" was prepared by Mr. E. O. Wooton, Associate Agricultural Economist of this division. This will conclude our co-operative efforts on this project for a temporary period. It is our purpose to make further observations in this same area in the near future.

Generally considered, the farming business in the plains area, according to our preliminary report, is safely solvent. From 10 to 15 percent of the farms included in this survey had no mortgage indebtedness, nearly half of them had only a small indebtedness, only about one-third had heavy indebtedness and of these only a small part were in danger of financial ruin. It is of interest to observe that many of the farm operators who were consulted reduced the amount of their indebtedness during the year 1922. It was shown further that about two-thirds of the 70 farmers in Lincoln County and three-fourths of the 81 farmers in Washington County had made gains in net worth since settling in this region. This was accomplished without taking into consideration the natural increment in the value of their lands. The increase in the value of farm lands in this area, especially for those who came into these districts several years ago when land was cheap, was considerable. There is no question but that some of the men who bought their farms during the war-time boom period paid, or agreed to pay, too much money for their land.

Report of Progress on Project No. 3.

The cost records which were secured from men who are producing beef cattle on the range were analyzed and a preliminary report entitled "An Economic Study of the Costs and Methods of Range Cattle Production on 41 Ranches in Colorado for the year 1922" was published and distributed. This report was written by Mr. G. S. Klemmedson of the Bureau of Agricultural Economics, U. S. Department of Agriculture. An additional report relating to costs and methods of carrying cattle on national forest ranges in Colorado, Wyoming, Montana, Utah and Idaho in 1923 was also prepared and distributed. Plans have been made to continue this project another year at least.

In the preliminary statement which has been issued relative to costs and methods in the range-cattle business, it has been suggested that if cattle are to be produced at a profit in the immediate future it will be necessary to have a perceptible increase in the market price of beef cattle or the operator must face the other alternative, namely, to decrease production costs. In order to reduce present costs, operators must of necessity give more attention to the better utilization of the range. The condition of the range determines largely the marketability and price which well-bred cattle command. Serious consideration should also be given to the means of increasing the calf crop by better management of the breeding herd. This may be done by providing the proper amount of range to maintain the cattle in good flesh, by owning the proper number of well-bred bulls, by culling non-productive cows, and by holding the breeding herd in small pastures before turning out on the open range.

Report of Progress on Project No. 4

Detailed farm-accounting records were maintained on some 26 farms during the past year. These records include complete information regarding the hours of man and horse labor required in handling

each farm enterprise; also the measured acreage and the total production for the crops grown together with the details showing the current farm expenses, crop sales and livestock-feeding operations. Two preliminary reports were issued during the year. One of these contains an analysis of the sheep-feeding operations on these farms for the year 1922-23 and 1923-24; the other involves an analysis of the cattle-feeding operations on these farms for the same periods.

Sheep feeding as conducted in the Poudre Valley may be counted as a supplement to the regular farming operations. It uses labor that would otherwise be idle during the entire season; it makes it possible to grow roughage which may be utilized in the feedlot. The accumulated manure when returned to the soil not only adds to the store of plant food in the soil but it assists in bringing about a better physical condition. If these indirect benefits were omitted entirely, the records show that the returns from sheep feeding pay market prices for everything fed or used and approximately one dollar per head remained clear profit. Price fluctuations introduce a certain degree of risk into the business but apparently this risk is no greater than in other farm enterprises.

Report of Progress on Project No. 5

The report on Rural-Life Studies last year indicated that records had been obtained from approximately 1000 families in a typical small town located in a prosperous agricultural district. Similarly 100 successful farm families representing important types of farming in different parts of the State were interviewed. These records are being tabulated and summarized. It is our expectation that it will be possible to prepare and distribute at least two preliminary reports giving the results of these two rural surveys.

Respectfully submitted,
L. A. MOORHOUSE,
Agricultural Economist.

REPORT OF THE ENTOMOLOGIST

To the Director:

Following is a brief report of the work of the Entomology Section during the past year:

There have been no changes in projects or personnel since my last report. Some of the lines of work under the project, General Insect Investigations, have been different than in former years. The losses from insect pests have not been greater than in average years.

Mr. George M. List, who devoted most of his time to the work of the State Entomologist, has been granted a leave of absence for one year to pursue graduate work at the Iowa State College.

Plant-Louse Investigations

The work on this project by Miss Palmer and the writer has been continued chiefly in the preparation of an annotated list of the aphids occurring in this State. It is anticipated that a portion of this list may be ready for publication during the coming year.

Ants of Colorado in their Relation to Plant Lice.

Professor C. R. Jones, who is in charge of this project, has made good progress in his work during the year, but the number of species that are being studied is large and it is probable there will be no paper for publication for some time to come.

Codling-Moth Studies

The work on this project has been carried chiefly on the funds of the State Entomologist, in the vicinity of Grand Junction by Mr. Wm. P. Yetter, Jr., and in Delta County by Mr. J. H. Newton. Considerable attention has been given to the use of attractive liquids for the capture of the moths. The results of this work will be given out in circulars from the office of the State Entomologist or in bulletins from the Experiment Station from time to time.

Considerable work has also been given to a study of the use of oils as ovicides for the Codling Moth, and to keeping orchardists informed as to the seasonal development of the Codling Moth so that the sprays might be applied at the proper dates.

Grasshopper Control:

Grasshoppers have been more severe the past summer in their attacks upon field crops, especially alfalfa, corn and wheat, than for several years past. A large amount of poisoned-bran mash has been used in the State for their control, and, in most instances, with quite satisfactory results. More than 1000 packages of prepared poison in condensed form have been sent to farmers from this office at actual cost during the summer and early fall.

Anabrus simplex, which was so very destructive to crops in Moffat counties last year, appeared in large numbers the past spring and was again quite destructive, but we did not have funds to put on a special campaign for its control as we did last year.

General Insect Investigations

Under this general project our chief work during the year has been with the Mexican Bean-Beetle, *Epilachna corrupta,* and with the Oyster Shell Bark Louse, *Lepidosaphes ulmi.* The former has been spreading thru Delta County and has become established in Mesa County the past year. It promises to be one of the most serious pests to beans on the Western Slope in the future. It did rather serious damage to beans being grown for the cannery in Delta County this year.

The Oyster Shell Bark Louse has become a very serious pest to the shade trees in Fort Collins and in some other sections of the State, especially to the ashes, cottonwoods, willows and purple lilacs. Investigations to determine the best means of control are in progress and have been in charge of Mr. List. This work will be reported upon later thru bulletins or circulars.

The Alfalfa Nematode, or Eel-worm, *Tylenchus dipsaci,* which was first reported in the State in the vicinity of Canon City in the spring of 1923, has been found upon a fairly thoro but hasty survey of the State, made in co-operation with the Federal Bureau of Plant In-

dustry and the Botanical and Bacteriological sections of this Station, to be very widely distributed in Colorado. It was found to occur in practically all of the alfalfa-growing sections. It was found to be rather common in the alfalfa fields of the Western Slope, and to occur occasionally in northern Colorado in Weld and Larimer counties, and it was also taken in the Arkansas Valley from Canon City to Lamar. As a study of the distribution of this nematode progressed, it became more and more evident that the severe dying out of alfalfa that occurred in many places the past spring and summer was not, to any considerable extent, due to this parasite.

In many fields the alfalfa crowns were decaying and dying to such an extent that it was almost impossible to find a healthy plant; while in others, where the nematode could be readily found in any part of the field, the alfalfa was doing well and the owners did not notice that there was any diseased condition present. While it is entirely possible that this Eel-worm may be found, on fuller investigation and under conditions favorable to its development, to be serious enough to demand close attention, I believe it would be a mistake, at this time, to put out any incendiary articles concerning it. It can probably be controlled by suitable methods of crop rotation. We plan to continue our investigations concerning this important pest to determine more fully its abundance, its distribution in the State, and the extent of its injuries and to report conditions from time to time.

The Alfalfa-Weevil control has been in direct charge of Mr. J. H. Newton, who is stationed during the greater part of the year at Paonia, Delta County. A considerable part of Delta County, a comparatively small area in Montrose County, and a very small area in Gunnison County, are infested with this insect, but so mildly that, for the past two years, very little damage has been done. In fact, the weevil has not been present in sufficient numbers to enable Mr. Newton to get a good test upon control measures. It seems further, that the little parasite *Bathoplectes curculionis*, which we introduced into the infested area soon after the presence of this weevil became known, may be largely, or possibly entirely, responsible for the large reduction in its numbers in the infested areas.

Mr. J. L. Hoerner has given his time chiefly to the work in the insectary, to the insect collection, and to a few important garden pests, especially the Potato Flea-beetle, *Epitrix cucumeris*, and the Mexican Bean-Beetle.

A technical paper of 58 pages, entitled "New Colorado Lachnini," giving the results of a rather thoro study of the plant lice attacking conifers in Colorado, was published in the March number of Annals of the Entomological Society of America, in joint authorship with Miss M. A. Palmer. The paper describes 18 new species and contains four full pages of colored plates, two pages of halftones, six pages of zinc etchings and two figures in the text.

Respectfully Submitted,
C. P. GILLETTE,
Entomologist.

REPORT OF THE FORESTER

To the Director:

The work of the year has been concerned with completing the project on Timber Decay, which is the only one in force. The last of the test specimens was removed from the culture box in June, last, and during the summer the data from the investigation were plotted in graphic form to show the relation between loss of weight, due to decay, and loss of strength in the wood.

A report on the project is now being prepared as rapidly as time left from teaching permits. Considerable library and reference work has been found necessary in order to learn what has been done along similar lines.

Arrangements have been made with the Forestry Department of the Michigan Agricultural College to use part of the report in connection with a thesis for the degree of Master of Forestry from that institution. The part of the report to be used is the description of a preliminary investigation carried on just before the present project was inaugurated under the Experiment Station.

Respectfully submitted,
B. O. LONGYEAR,
Assistant in Forestry.

REPORT OF THE HOME ECONOMICS SECTION

To the Director:

During the year 1923-24 work on the different problems of this section has been carried on as follows:

I. The Cooking Quality of Colorado Potatoes.

a. The scientific data obtained in the course of the experimental work of this laboratory has been compiled for comparisons and conclusions. The bulletin embodying this data is being written.

b. The manuscript for a housekeeper's bulletin on this subject is nearly ready for publication. A food supplement to this bulletin seemed necessary. The manuscript for this supplement is ready.

II. Bread-making Qualities of Colorado Flours.

Experimental work on this problem is nearly completed. A housekeeper's bulletin on the subject has been begun. It is hoped it will be completed within a few months.

III. Principles of Making Fruit Jellies.

Examinations of and experiments with Colorado fruits regarding their jelly-making properties have been in process. This research supplements a detailed study of the principles of jelly-making carried out and published by the writer in 1908-'11 at the University of Illinois. A new bulletin for housekeepers, embodying the results of all these researches is nearly ready for publication.

Respectfully submitted,
N. E. GOLDTHWAITE,
Home Economics Investigations

REPORT OF THE HORTICULTURIST

To the Director:

I beg to submit the following brief report of the status of the experimental work carried on by the Horticulural Section.

ORCHARD-MANAGEMENT PROJECT

The work is carried on at the College fruit farm, Austin, Delta County. The project includes methods of cultivation, cover crops, pruning and thinning. The results show conclusively a lack of thorough cultivation in Colorado orchards. This neglect necessitates more frequent irrigation and the use of large quantities of water. Proper soil conditions cannot be maintained with this practice and the effect upon production is very apparent.

Experiments with the use of cover crops have been delayed in order to get the orchard into a uniform condition so that the results will be comparable between the different kinds of crops to be used. Cover crops are now extensively used in Colorado orchards, but as yet no definite system has been worked out. There is a tendency to sow perennial crops and to let them grow for a number of years,—a practice that is not conductive to best results.

The work in pruning shows that our apple trees carry too much wood for the production of high-grade fruit. This is particularly true of the older orchards. Size of fruit is greatly affected by the growth vigor of the trees and in order to maintain size of the fruit, more thorough pruning is necessary.

Thinning Fruit

Experiments on thinning peaches have been in progress for the past two years. The results are conclusive. A block of peaches was carefully thinned after the June drop. This block packed out 99½ percent extra fancy, while the unthinned block packed out 60 percent. The results for the two years were almost identical.

Variety Testing

During the past two years, testing plots of apples, pears and plums have been planted. These variety plots are all doing well with the exception of the sweet cherries. A number of new varieties are being tried, as well as varieties which are not at present grown in the State commercially.

GRAPE PROJECT

The grape industry in Colorado has, in the past, been neglected. The results obtained from the small home plantings show that both the European and the American varieties of grapes can be grown successfully in the warmer valleys on the Western Slope, and that the American varieties succeed exceptionally well in the Arkansas valley from Canon City to LaJunta. In order to furnish the needed information on grape growing in Colorado, an experimental vineyard was started two years ago on the College fruit farm and additional plantings

were made last spring. Both American and European varieties are being used, the object being to determine hardiness and adaptability of different varieties and also to study their behavior under different methods of culture and training. The outlook for the grape industry is very promising.

POTATO PROJECT

Potato Certification

This work is very important to the potato-growing industry, as it tends to keep up the yield of the crop. It has been in operation for the past five years and is constantly growing. Certified seed is grown under close supervision of the department, and two field inspections are made during the growing season. Before certification is given, the grower must comply with all the rules and directions laid down by the department as well as pass the field inspection. The rules cover the character and source of the seed planted and cultural methods. The inspection covers freedom from diseases, vigor of the plants and trueness to type. The grade must be U. S. No. 1.

Seed potatoes, grown under the conditions described above and certified, carry the department certification tag and are sold under it. The price obtained by the growers for certified seed has been $3.00 per 100 pounds during the past five years. The growing of certified seed is mostly confined to the non-irrigated lands and to higher altitudes.

Farmers' Seed Plot

To encourage the individual potato growers in planting better seed potatoes, the seed-plot method of seed improvement was inaugurated this year in co-operation with the county agents in the San Luis Valley. The growers were to select the best possible tubers from their past year's crop and plant these separately, enough seed to be selected to furnish seed for the total planting next year. These plots were to be given the best care possible during the growing season. The plots were inspected by the department and rogued of diseased plants, of weak hills and of mixture.

By this method we hope to build up a given variety or strain and increase the production of higher grades of table stock. Seed plot potatoes should not be confused with certified seed.

Potatoes on College Farm at Avon

The first year's work at Avon was more or less unsatisfactory. In the first place the rotation system practiced before we took over the farm was such as to make potato growing unsatisfactory. Further, the land was "potato sick." A longer rotation period must be followed together with a greater diversity of crop. This will be possible in the future.

VEGETABLE PROJECT

Head Lettuce

The head-lettuce industry is still expanding and the high prices obtained this year will stimulate the industry further. We are carrying on work with head lettuce along the following lines: Cultural methods, irrigation, early and late planting, planting of seed obtained from different sources, and control of tipburn, as well as studying the effect of temperature and moisture upon the development of disease. Testing plots of cauliflowers, carrots and rutabagas were grown to determine their adaptability to high altitude. These plots were of sufficient size to produce trial shipments to obtain data on prices and profits of production.

Green-Pod Peas

The growing of green-pod peas in high altitudes started three years ago. The peas arrive on the market when pod peas grown in the lower altitudes are not obtainable. The high quality prices obtained, assure the growers of a handsome return. The crop would be grown more extensively, were it not for the problem of obtaining the necessary labor in picking the pods.

Seed Peas

This year an experiment was started to determine whether seed peas could be grown in high altitudes. Four and one-half acres were planted under ordinary field conditions. The varieties grown were the Dwarf Telephone and the Alderman. During the growing season the field was carefully rouged to eliminate mixtures and weak plants. The crop matured perfectly and was harvested. Threshing is now in progress. The yield promises to be good. The seed has been sold to a seed company in Denver for 10 cents per pound, and they are anxious to make a contract for next year. The prices should give a handsome profit to the farms, since the cost of production is low.

Peas for Canning

In order to test the quality of our mountain peas for canning, a number of canning varieties were grown on limited areas. When they were in proper state of maturity, 500 pounds were shipped to the Libby, McNeil and Libby canning plant at Manzanola to be canned. The result of the canning test was very encouraging. The foreman expressed the hope that they might obtain canning peas of like quality. He also stated that it is very difficult to obtain high-grade canning peas, and the market was paying almost any price for the right quality. There is a wonderful future for the pea-canning industry in our high altitudes, for the quality of our mountain pea is unexcelled. They yield heavily and can be grown at a low cost.

VEGETABLE PROJECTS AT THE COLLEGE FARM

Celery

For the past three years, we have been testing varieties and strains of celery. This work was undertaken to aid the celery growers around

Denver in finding a variety or a strain that would meet the demands of the market and at the same time produce a satisfactory return to the growers. The Denver section produces large quantities of both early and late celery, but the standard varieties of these two kinds have not proved satisfactory. The result of our work, thus far, has shown that certain strains of both early and late varieties possess the required qualities, and these will be recommended to the growers in a bulletin to be published shortly.

Hubbard Squash

Efforts are also being made to develop a strain of wilt-resistant squash by selection. This work is necessarily slow, and will require several years to complete.

TOMATO PROJECT

For the past two years, we have been co-operating with Libby, McNeill and Libby in the development of better canning tomatoes. This work has been in progress for two years. Last year, due to the late spring frosts and destructive hail storms, no results were obtained. This year we had ideal weather conditions and the work accomplished was satisfactory.

The work is centered on two lines: First, to find a variety or varieties of tomatoes that will make a satisfactory yield and have the required canning qualities; Second, to cross the best canning varieites and to grow or plant from the cross-bred seed. It has been found that cross-bred seed produces high yield and high quality for the first year. We now have on hand from the summer's work a sufficient amount of cross-bred seed to grow at least an acre under average farm conditions. This work will be continued.

In conclusion, I wish to express my appreciation for the uniform support the department has received and for the personal interest you have taken in our work.

Respectfully submitted,
E. P. SANDSTEN,
Horticulturist.

REPORT OF IRRIGATION AND DRAINAGE INVESTIGATIONS SECTION

To the Director:

During the fiscal year ending June 30, 1924, the work of this section has been confined to the projects mentioned below.

As reported last year, the improvements made to the Venturi flume, an Adams project, have now been verified, both by laboratory and field tests, and show that this new device has wonderful possibilities. The laboratory work necessary in the development of this improved Venturi flume was done both at the Fort Collins and Bellvue laboratories. The calibration covered flumes of 1, 2, 3, 4, 6 and 8 feet in length for both free-flow and submerged conditions. A maximum of 62.5 second-feet

was used in the calibration of the larger sized flumes with a minimum of 0.3 second-foot for the 1-foot flume. The study of this type of flume reveals the fact that, due to the formation of a hydraulic jump within the structure, a marked degree of submergence is possible before the discharge is reduced from that of the free-flow. It is observed that as the width of the throat, or size of flume, increases, the degree of the resistance to submergence also increases. For the smaller flumes, the degree of submergence allowable is 70 to 75 percent, while for the larger sizes, this degree of submergence is from 75 to 80 percent. One great improvement over the Venturi flume has been the elimination of the throat reading as a function of the discharge, where the degree of submergence is not greater than about 75 percent. During April, a number of these flumes were installed in the Arkansas Valley, being used in connection with the Duty-of-Water study. These flumes varied in size from a throat width of 6 to 36 inches. Because of the great quantity of sand and silt carried in the irrigation water of the Arkansas Valley, this improved device has been found to be especially well adapted to meet the conditions as found there.

To observe the action of this type of measuring device a wooden flume with a 6-foot throat was constructed in the Rocky Ford ditch at Rocky Ford. The capacity of this ditch was about 90 second-feet. This flume has been under constant observation and at all times has been clean of deposit; however, the width of throat is somewhat too great to insure a free-flow condition. Under the present dimensions it has a submergence of from 85 to 95 percent. On a large lateral from the same ditch an improved Venturi flume was built with a throat width of 3 feet and a depth of 3 feet. Close observations have been made as to the action of this flume and it was found that if the difference in head (upper head minus throat head) was not less than 0.05 foot, no deposit would occur; however, if the difference be reduced to 0.02 foot, a deposit was immediately accumulated in the depressed floor of the throat section. A large flume with a 10-foot throat was constructed in the Holbrook Ditch near Rocky Ford. Since the installation, only general observational data have been secured. Nearly 600 second-feet have been measured through this structure, but because of shortage of water a complete calibration of this large flume has not been possible.

The improved Venturi flume possesses three important characteristics, namely, it is accurate, is self-cleaning, and successfully operates under a small loss of head.

Under the Hatch fund two projects have been carried: the Evaporation Experiment and the Measurement of Water as applied in irrigation. As reported last year, the Evaporation-Experiment studies have been carried both within and without the laboratory. Inside the laboratory further observations were made relative to the effect of wind. Under still-air conditions within the laboratory, the data indicate that as the difference in temperature increases, that is, temperature of air minus temperature of water, the rate of evaporation decreases. Wind affects the rate of evaporation, but sufficient study has not yet been

made to isolate the direct effects of this factor. Sufficient observations, under still-air conditions, have now been made to definitely say that within the laboratory the maximum rate of evaporation occurs about sunrise in the morning. The evaporation observations taken under fully exposed conditions outside the laboratory show the rate of evaporation to be greatest during the afternoon. The experiments in evaporation have been confined to observation on pans three feet square. To ascertain the relation of these smaller pans to a water surface of moderate size, it was necessary to waterproof carefully the circular reservoir at the hydraulic laboratory for the purpose. The comparative results of these observations are not yet available.

The project on Measurement of Water has included special studies on devices at the hydraulic laboratory. A series of observations was made to determine the accuracy of the Great Western irrigation meter. This instrument operates in connection with a submerged orifice; that is, for a certain effective head on the orifice this same head is operative on the instrument. Because of the variation in the constant discharge, and further, because of the instrument being built for a definite constant of discharge, the relation only agreed within certain limits of head.

Under this project special study was made concerning the effect upon the hydraulic jump formed in a contracted section caused by a parabolic floor. It was discovered that such an arrangement might be a very desirable improvement to the present improved Venturi flume. Tests were conducted as to the possibility of using positive and negative pressure heads as a means of indicating the effective heads in connection with the discharge through the improved Venturi flume.

No improvements have been made at the Bellvue laboratory this year.

Under State funds, the projects in Meteorology and Duty-of-Water Study in the Arkansas Valley have been carried during the past fiscal year. The work in Meteorology has been a continuation of that in past fiscal years, consisting in the observation of meteorological conditions twice daily (7 a. m. and 7 p. m.), the posting of weather bulletins each day, and the publishing in local papers of the more important weather data and reports.

The Duty-of-Water Study in the Arkansas Valley has now been conducted over a period of three consecutive years. This study has been carried on in two parts; first, where special observations have been made on experimental plots, and, second, where close record has been made as to the use of water on several farms in the valley. Our irrigation studies made in connection with the experimental plots, especially with sugar beets, have not been entirely successful. Fair records were obtained the first year from our plot studies. However, no marked effect was observed in yields where varying increased or decreased amounts of water were applied to various individual plots. Considerable variation in yield also existed as to the amount of water used per acre of beets by the several farmers co-operating in our study.

At the outset of our co-operative work with the American Beet Sugar Company at Rocky Ford, a comprehensive program as to

rotation was assumed. The second year's work on the plots required the planting of beets on ground previously planted to this crop. Adverse weather conditions existing after the young plants were started necessitated three different times. This handicap, together with bacterial infection later in the season, resulted in a poor yield sufficient to vitiate results or effects of irrigation. During this second year, the farm studies were continued and some substantial results obtained. In general it may be said that on a medium sandy-loam soil frequent and light irrigation of sugar beets is to be recommended. A rather wide variation in the duty of water for various crops, as observed on the special farms, was again noted. The records relative to the season of 1924 are not yet available, but it is expected that some very interesting and important information will result from the standpoint of irrigation.

In addition to the work on projects, considerable time has been given to special assignments throughout the State, this additional work consisting in giving assistance in the drainage of irrigated lands and measurement-of-water problems, both for farmers and ditch companies.

Respectfully submitted,
RALPH L. PARSHALL,
Irrigation Engineer.

REPORT OF THE VETERINARY PATHOLOGIST

To the Director:

PROJECTS IN FORCE

I. Sheep Losses in the Feedlots

(a) Hemorrhagic Septicemia,
(b) Paratyphoid Dysentery,
(c) Icterohematuria,
(d) San Luis Valley,
(e) Overfeeding on grain.

II. Contagious Abortion

III. General

SHEEP LOSSES IN THE FEEDLOTS

Hemorrhagic Septicemia

This disease was very rare during the last year, consequently only routine typing work on the organisims previously isolated was attempted. This seems to indicate that the organisims do fall into different groups as measured by the agglutination tests.

Paratyphoid Dysentery

A very serious outbreak of paratyphoid dysentery, involving some 30,000 lambs, occurred in the Fort Collins district during October, 1923. The total loss was approximately 2,000 head. A very thorough investigation was made by this Section, which resulted in the isolation of the organism responsible, in the reproduction of the disease in

healthy animals, and in the determination of the relation of fasting to the disease. A complete report was presented under the authorship of the undersigned and Floyd Cross, at the meeting of the American Veterinary Medical Ass'n, at Des Moines, held in August, 1924. This will be published in an early number of the journal of this association.

Briefly, this disease was described in sheep for the first time. It was shown that large doses of the organism could be given to healthy animals without their showing any symptoms, provided they were fed continuously. If however, they were fasted for forty-eight hours, small doses by the mouth would produce a fatal disease. This work was suggested by the fact that the outbreak was in lambs which had gone a considerable length of time without feeding, during shipping. It indicated that special precautions should be taken to see that lambs be fed at frequent intervals while in transit. Mere fasting would not produce the disease, but fasting in connection with the organism was fatal.

Icterohematuria

This disease continues to take its toll from the older sheep in the mountainous districts. We have now definitely located it in practically all of the mountainous areas from Steamboat Springs to Durango. It seems to be getting more serious. While we have been able to visit a number of outbreaks and have gathered material for study, we are still very much in the dark as to its cause and means of control.

San Luis Valley

Last year we turned this experiment over to the Animal Husbandry Section, retaining only an advisory relationship. Since the disease has been thought by some to be due to the malignant *Edema bacillus,* we prepared filtrates from these organisms and vaccinated one-half of the lambs used this year, simply to obtain information as to the possibility of this filtrate being of value in the prevention of the trouble.

Overfeeding of Grain

The losses in the Fort Collins district during the last season were approximately three percent, being the same as the previous year. Most of this loss occurred in the corn-fields or on heavy grain-feeding in the pens. It took place in the lambs that were nearly ready for market and in those that were getting heavy grain rations. In all cases cutting off the grain ration was sufficient to stop the loss. Mr. Bartels kept an accurate record of the amount of grain fed, and the loss for each day during the feeding period. A chart showing this relationship was prepared and exhibited by Mr. Bartels to the sheep feeders on Feeders' Day. This established very conclusively, that with the increase in the grain ration the death loss mounted up. When the grain ration was cut the death loss ceased. We have this year distributed charts to a large number of the feeders with a view to getting this record kept on a large number of lambs, in the hope that by spring we shall have a larger amount of data on this very important question.

CONTAGIOUS ABORTION

Two years ago we entered into a co-operative arrangement getting more correct data on the use of the live-organism vaccine for contagious abortion. After carrying on these studies for two years we have found it necessary to discontinue the work, because of the lack of co-operation on the part of the owners. In the meantime the disease has vanished from the herds.

There was, however, a very serious explosion in the College herd during the past year which we have followed very carefully, making blood tests at frequent intervals, and separating the animals into two groups on the basis of test. By close co-operation on the part of the Animal Husbandry Department we have been able to eliminate the disease entirely from the herd. In the future, no animals are to be added except after two tests made at a thirty-day-interval, with isolation of the animal in the meantime. We believe we have shown here a practical application of the present theoretical knowledge in relation to this most serious malady.

Abortion tests have been made as usual for all those sending in blood. As a result, during the past year, we have made 684 tests, 119 of which were positive, or 17.3 percent.

GENERAL

We have continued to make diagnoses in the laboratory for all those wishing to make use of our services. Six hundred twenty-two (622) lots of specimens have been examined during the past year.

Owing to the seriousness of White Diarrhoea in chickens, special attention has been given to eliminating the disease from the flocks of the State. In connection with this work we have made 2325 blood tests which showed 438 positive reactions, or 19 percent. We are expecting this work to increase very materially in the next year.

A considerable number of trips have been made with a view to investigating special outbreaks of disease, among the most prominent of which have been:

Arsenical poisoning in sheep, with a loss of 70 head, near Brush, Colo.

Potato poisoning in horses in the San Luis Valley with quite a heavy loss.

Forage poinsoning the Arkansas Valley.

Miss Beulah Malone, technician, resigned to take effect September 1, and was replaced by Miss Ruth Harrison.

Respectfully submitted,
I. E. NEWSOM,
Veterinary Pathologist

REPORT OF THE VETERINARIAN

To the Director:

The only project allowed in the Veterinary Section is the one on Animal Diseases. This is a general project and takes care of a certain phase of animal-disease investigation in a very satisfactory way. It is not only helpful in emergency cases, which appear from time to time, but enables us to keep in touch with livestock conditions throughout the State in a general way, and to lend assistance when called upon by State or National authorities.

Only one disease, assuming epizootic proportions, has appeared among animals in the State during the past twelve months. *Mycotic stomatitis* has been wide-spread among horses and cattle in the western states during the past summer and fall. It is now apparently subsiding. The mortality has been comparatively insignificant, but the economic loss has been considerable, mostly because of the loss of flesh and milk during the periods of sickness and convalescence.

The dread foot and mouth disease, which appeared in California and Texas, seems to be well under control, but is still an element of danger which will require eternal vigilance until it is definitely stamped out.

An experiment conducted at Walsenburg during the early summer was decisive in establishing the fact that cattle, at least, are seriously poisoned by eating the leaves of scrub oak.

From the standpoint of communicable diseases, the domestic animals of the State are exceptionally free at this time.

We wish to continue during the present fiscal year with the one project of Animal Diseases.

Respectfully submitted,
GEO. H. GLOVER,
Veterinarian

ENGINEERING DIVISION

To the Director:

I am transmitting herewith the report of the Civil Engineering and Mechanical Engineering sections of the Experiment Station.

Respectfully submitted,
L. D. CRAIN,
Vice-Director

REPORT OF THE MECHANICAL ENGINEERING SECTION

To the Chairman, Engineering Division:

The following is a summary report of the investigational work carried on in the Mechanical Engineering Department of the Engineering Experiment Station during the Federal fiscal year, July 1, 1923, to June 30, 1924:

The projects upon which the Mechanical Engineering Department was engaged were: (1) Testing of Lubricating Oils; (2) Treatment of Alkali and Other Waters for Domestic Use.

The projects upon which we would like to prosecute work during the present fiscal year are: (1) Completion of the project Testing of Lubrication Oils; (2) The Humidity of Air in Buildings. The project, Treatment of Alkali and Other Waters for Domestic Use, was completed during the first part of the present fiscal year.

Further outline of the work has not been made to date since the projects under investigation at present will probably occupy the entire fiscal year.

The more important conclusions reached during the investigation on "The Treatment of Alkali and Other Waters for Domestic Use" are:

(1) The domestic water supplies of Colorado, as a whole, are good, although alkali waters may be found in practically every section of the State.

(2) The ill effects of alkali water, although they may not disappear, are not particularly objectionable after a person becomes accustomed to drinking alkali water unless it is extremely alkaline.

(3) A deep well, either for an individual or a community, will often solve the problem of domestic water supply.

(4) Distillation is the only method by which alkali water may be purified for drinking purposes.

(5) Household water stills now on the market are simple, convenient to operate, and inexpensive, but considerably over rated. For instance, one still was rated as high as 1 to 6 quarts per hour and the maximum capacity under laboratory conditions was found to be .86 quarts per hour. A household still operated on the back of a kitchen stove with an ordinary fire will not produce enough distilled water for an average family, but it must be operated directly over a fairly hot fire to produce from 1 to 2 gallons of distilled water every 10 hours.

(6) Water may be distilled from 10 to 15 percent cheaper with coal than with artificial gas, although 9 times as much heat must be produced in a coal stove as with a gas burner to distill the same amount of water.

Respectfully submitted,
G. A. CUMINGS,
Aissistant in Mechanical Engineering

REPORT OF CIVIL ENGINEER

To the Vice Director:

Following is the report of the Civil Engineering section of the Experiment Station and covers the experimental work done by the section from July 1, 1923, to June 30, 1924.

Two projects have been under way during this time; (1) The Effect of Beet Pulp on Concrete; (2) Co-operative Work with the State Highway Department covering the Road Materials of Colorado.

A report covering the results of the investigation to determine the effects of beet pulp on portland cement mortar and concrete is nearly complete, but is being delayed in order that additional data may be secured on a few minor points. A bulletin covering this work should be ready for publication early in 1925.

The co-operative agreement between the State Highway Department of Colorado and this section, entered into in 1921, is still in effect. The field party during the year has consisted of two men. The chief of party, who worked throughout the entire year, was employed by the Highway Department. One helper, who worked during the summer season only, was furnished by this section.

In the laboratory, no regular extra help has been required. Student assistants have been employed when the work was more than the testing engineer could do.

During the period covered by this report, samples from 192 deposits of road materials located by the field party have been tested in the laboratory. A total of 244 samples from all sources have been tested. A system of State highways has now been practically covered by the field party.

We are unable to state as this time just what our plans will be for next year, as they will depend to a large extent on the State Highway Department. If the co-operative agreement is continued, their wishes of course will be paramount.

The purpose of this project, as originally stated, was "To Test the Road materials of Colorado and determine those best suited for surfacing the earth roads of the State; to construct sample sections of roads surfaced with the materials available; and to secure data whereever possible as to the wearing quality of these materials." Our work to date has dealt largely with the first phase of the project. Future plans should include a consideration of the last two phases, at the same time keeping the laboratory equipment in readiness at all times to do such testing as may be requested by State, county or city officials within this State.

Respectfully submitted,
E. B. HOUSE,
Civil Engineer

REPORT OF THE EDITOR OF PUBLICATIONS

To the Director:

Although a less number of bulletins was published by the Experiment Station this year than last, Station workers are preparing several which cannot be included in this year's report. This office has assisted in preparing illustrations for several of them.

In addition to several news stories concerning the work of the Station, special publicity was given the division through special stories for New Year and other editions of State papers.

Programs and circulars announcing the annual Lamb Feeders' and Cattle Feeders' Days were handled through this office. Several stories were also distributed concerning these particular events.

Six new bulletins, two reprints and the annual report, consisting in all, of 248 pages, and a combined edition of 28,000 copies, were published for the Experiment Station during the year.

Following is a complete list of the publications:

Title and Author	Pages	Edition
287—Grasshoppers Control in Colorado C. L. Corkins	20	4000
288—The Pit Silo John W. Sjogren	12	3000
289—Necrobacillosis Geo. H. Glover	12	3000
290—Beautifying the Home Grounds E. Monroe Lowry	20	4000
291—The Effects of Nitrates on the Composition —of the Potato William P. Headden	32	2000
292—Hardy Varieties of Apples for Northeastern Colorado E. P. Sandsten	8	5000
Thirty-Sixth Annual Report	40	1500
Reprints		
259—Colorado Plant Diseases Julian G. Leach	96	3000
262—Sod Disease of Chickens I. E. Newsom and W. H. Feldman	8	2500
	248	28,000

Respectfully submitted,
I. G. KINGHORN,
Editor of Publications.

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